Technology Demonstration of Sensor Applications to Direct Push Platforms and Monitoring and Operations

Contract # F41624-00-C8045

Technical Report for Field Test 6
Period of Performance: December 11 – 17, 2003
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14. ABSTRACT
Dakota Technologies, Inc. (DTI) demonstrated a real-time, direct push halogen specific detector (hereafter referred to as the Haloprobe) with the US Army Corps of Engineers (USACE), Kansas City District (KCD) Site Characterization and Analyses Penetrometer System (SCAPS) crew. In December 2003, Mr. Jerry Hansen of Air Force Center for Environmental Excellence (AFCEE) coordinated the effort to mobilize equipment and personnel to a site on the former Rickenbacker Air Force Base in Columbus, OH. This site provided an excellent opportunity to train the SCAPS crew on the Haloprobe operations and to provide beneficial subsurface information to Shaw Environmental and the Air Force Real Property Agency for delineating trichloroethene (TCE) contamination near site Building 848. The work occurred in two phases, totaling 5 working days. 36 pushes were advanced, including 27 with the Haloprobe, 5 with laser induced fluorescence (LIF) probe, 3 for collection of soil samples, and 1 to condition a replaceable membrane.

15. SUBJECT TERMS
Halogen Specific Detector, Haloprobe, chorinated solvents, sensors, direct push, continuous logs, real-time, in-situ, MIP, membrane interface probe, LIF, fuels, SCAPS, CPT

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Background and Introduction

Dakota Technologies, Inc. (DTI) demonstrated a real-time, direct push halogen specific detector (hereafter referred to as the Haloprobe) with the US Army Corps of Engineers (USACE), Kansas City District (KCD) Site Characterization and Analyses Penetrometer System (SCAPS) crew. The SCAPS vehicle is shown in Figure 1. In December 2003, Mr. Jerry Hansen of Air Force Center for Environmental Excellence (AFCEE) coordinated the effort to mobilize equipment and personnel to a site on the former Rickenbacker Air Force Base in Columbus, OH. This site provided an excellent opportunity to train the SCAPS crew on the Haloprobe operations and to provide beneficial subsurface information to Shaw Environmental and the Air Force Real Property Agency for delineating trichlorethene (TCE) contamination near site Building 848. The work occurred in two phases, totaling 5 working days. 36 pushes were advanced, including 27 with the Haloprobe, 5 with laser induced fluorescence (LIF) probe, 3 for collection of soil samples, and 1 to condition a replaceable membrane.

DTI personnel constructed and lab tested the Haloprobe system prior to delivery to the USACE KCD facility. An attempt was made to field test the Haloprobe system in the KCD SCAPS in June 2003. This field test was unsuccessful and thought to be due to high operating temperatures. The system was returned to DTI in Fargo for analyses and modifications. In November 2003 the system was placed back into the SCAPS and the probe was successfully pushed at one location at Lake City Army Ammunition Plant on Monday, 24 Nov. However, after the first push, the probe was accidentally bent. The probe and umbilical cable were removed from the truck and brought back to DTI's facilities for repair. Upon completion of the repairs, the probe was sent to Rickenbacker IAP in Columbus Ohio for the field demonstration.

Objectives

1. To test the Haloprobe instrument constructed for AFCEE under a broad agency announcement (BAA) contract
2. To train KCD SCAPS personnel on the operation of the Haloprobe system
3. To collect high quality and quantity field data to characterize the extent of contamination from chlorinated hydrocarbons in the subsurface at Rickenbacker International Airport (IAP), Columbus Ohio

Figure 1. KCD SCAPS truck on location at Rickenbacker

Sensor Description

Haloprobe System

The Haloprobe system consists of a Membrane Interface Probe (MIP™ Geoprobe Systems) coupled with a halogen specific detector which functions identically to OI Analytical's high performance GC coupled halogen specific detector (XSD). Placing the detector downhole eliminates problems associated with returning the vapors to the surface (time lag, condensation, adsorption losses in transfer lines, and dilution of analytes in transfer lines).

The MIP consists of a small membrane of stainless steel mesh impregnated with a fluorocarbon polymer and mounted on a heating block. The heating block is mounted on the body of the probe and heated to temperatures above the boiling point of water. The hot surface of the heating block vaporizes volatile organic compounds adsorbed in the surrounding soil and dissolved in water. Subsurface VOCs, whether initially present as gaseous, dissolved, solid, or free product phases, pass through the MIP and are swept with a gas flow into the detector. Movement of species across the thin, heated membrane into the probe is rapid, requiring less than one second for light hydrocarbons. There is no bulk flow of gases or liquids across the membrane, which allows for efficient operation in both the vadose and saturated zones.

The carrier gas stream from the MIP passes to the halogen detector via a short (ca one foot) transfer line. Transit time from the MIP to the detector is less than two seconds. The Haloprobe employs a heated reactor (ca 1000 °C) in an oxidative mode, which pyrolizes any halogenated compounds to halogen ions, water and carbon dioxide. The Haloprobe response is highly selectivity for halogenated compounds relative to

nonhalogenated compounds (greater than 5000:1). The resulting ions produce a voltage that is subsequently read by the uphole computer. Real-time logs of total halogen contamination vs. depth are continuously generated as the probe is advanced through the subsurface. The probe is applicable for concentrations ranges from low dissolved phase (100 ppb-1 ppm) to free product.

Site Activities Rickenbacker IAP

DTI personnel arrived in Columbus, OH on Wednesday, December 10th at approximately 7:00 PM; the SCAPS crew arrived the following day after completing work at the former Newark Air Force Base which is nearby. On Thursday afternoon, 11 Dec, the Haloprobe sensor was strung onto the SCAPS push rods, the unit for probe temperature and flow control was set up in the SCAPS truck, a compressed air cylinder was procured, utility clearances were verified and permission was sought to use a nearby fire hydrant to obtain water.

On the morning of 12 Dec the Haloprobe system was started and allowed to come to operating temperature. During this time, a representative of Shaw Environmental selected the push locations and marked the locations in the field. The first thirteen pushes were made in the vicinity of a monitoring well which had elevated levels of TCE (1-2 ppm). These pushes were made to depths of 17.4 to 36.9 feet below ground. Cone or sleeve refusal was encountered in all but two pushes. The soil classification on the first push was lost due to an incorrect wire connection. The Haloprobe signal went off scale while making the first push so the electronic signal gain was changed from 1.0 to 0.1 to keep the signal within an observable scale However, cone refusal occurred shortly after the gain was changed so little additional information was gathered.

During this first day of pushing, the sensor appeared to behave normally until a replicate push was attempted at the end of the day. The replicate was attempted near Push 1 where contamination had been indicated in several areas but no contamination was found. This result was unexpected since the calibration procedure performed prior to each push was still giving signal. Lack of signal in the subsurface was attributed to a number of possible causes including too high of a flow rate through the controller, a worn membrane, a bad connector on the end of the detector signal wire, or a bad heating block.

On 13 Dec, the second day of work, the removable membrane in the heating block was replaced and a push was made to 26.5 feet. This did not solve the problem so it was determined that entire MIP heating block assembly was probably bad. Upon opening the probe a burnt electrical smell was immediately noted. Further disassembly showed that the smell was localized to the MIP area. Furthermore, two pieces of masking tape that had been used to differentiate the cone and sleeve wires had darkened as if exposed to smoke. When the MIP block was removed, some water was behind it, this is indicative of imminent block failure. Two extra replacement blocks were on hand.

Prior to installation on the probe, one of the replacement blocks was hooked directly to the MIP controller to determine the actual temperature at the membrane. However, as soon as the heater breaker was energized, the Geoprobe controller kicked off and the CPT truck’s UPS sounded an overload warning. The second MIP block was attached with the same result. It was determined that the replacement blocks which had been sent from the manufacturer were 50 volt rather than the 110 volt blocks that had been originally ordered . Since it was a Saturday and Geoprobe could not be contacted the Haloprobe system was idled until Monday, 15 Dec.

Visual or odiferous evidence of fuel was at the top of many of the thirteen pushes so while waiting to rebuild the Haloprobe, the SCAPS used laser induced fluorescence (LIF) to investigate the same area. LIF is sensitive to polycyclic aromatic hydrocarbons which are present in fuels, and thus are an indirect measurement of the presence of fuels. Five LIF pushes were made near several of the Haloprobe holes. These holes are identified as SCLIF01, SCLIF02, SCLIF07, SCLIF08, and SCLIF8.5. A fluorescence response indicative of hydrocarbons was noted in 4 of the 5 pushes between 5 and 10 feet and /or 10 and 20 feet.

One push (SCLIF8.5) had some response at the surface and a minor response at approximately 18 feet coincident with a clay-silty sand contact. The deeper response may be due to the presence of hydrocarbons or to some naturally occurring organics.

Upon receipt of the new blocks on Tuesday, 16 Dec, the Haloprobe was repaired and work resumed in the areas suspected to have TCE. Three Haloprobe pushes were made on Tuesday and nine were made on Wednesday.

Pushes 12 through 17 were made on the back or northwest side of building 848 before the end of the workday. Pushes 18 through 22 were made on the street or southeast side of building 848. Two additional pushes were also made in the first area, one between pushes 9 and 10 and the other south of push 8 in an area suspected to be free of contamination. On Wednesday, a slight delay was incurred when the truck engine water pump hose clamp broke and had to be replaced.

Three soil samples were obtained. Soil sample intervals were based on Haloprobe response. Three analytical samples were obtained with a direct push Vertek sampler and placed in jars provided by Parsons and in the custody of Shaw Environmental. Shaw Environmental handled all labels and custody requirements. Sample borings were placed as close as possible to the corresponding Haloprobe push. One sample was obtained from each of the three areas identified around building 848. Table 1 summarizes the soil sampling efforts.

Table 1. Soil Sample intervals and recovery

Haloprobe push ID	Depth Interval in ft	Recovery in ft	Soil Description
SCAPS 17	3.5 - 5.0	1.5	Fill, silt w gravel, moist, orange brown
SCAPS 01	4 - 5	1.0	silty clay, soft to med, diesel odor, green gray
SCAPS 22	5 - 6.5	1.1	silty clay, soft to med, oily odor, orange brown to gray

Holes were grouted from the top with cement grout or cement/bentonite grout. Water was obtained from a hydrant with permission of the Rickenbacker Port Authority.

Upon completion of Haloprobe work, the Haloprobe system and support equipment were packed for transport back to the KCD facility. DTI personnel left Columbus, OH to return to Fargo on the morning of 18 Dec.

Data Collection

Initial startup of Haloprobe system

The following startup procedure was used at the beginning of each day for the Haloprobe system:

The flow rate of air to the carrier gas delivery line was set to 30 mL/min with a backing pressure of 15 psig. The carrier gas return line was immersed in water to confirm that the carrier gas was flowing through the entire system. If adequate airflow was present, the data collection program was then started. Next, the heater controllers for the detector and MIP were turned on and allowed to come up to operating temperature; 130 ºC for the MIP and 1020 ºC for the Haloprobe Detector. Data collection continued until the baseline detector signal and detector temperature had been stable for five minutes. The run was ended, the data file name was recorded, and the data file was saved to the hard drive and a floppy disk.

Field calibration of Haloprobe system

Many factors influence the sensitivity (Δ signal / Δ chlorinated concentration) and the baseline stability of the Haloprobe system. Most can be controlled well enough to insure consistent behavior over time. Parameters such as detector and bias voltages can be controlled well enough to insure consistent behavior over time.

Other parameters cannot be controlled to prevent system drift in sensitivity and baseline response. The soil conditions constantly change as the MIP is advanced during a push. These changes can significantly affect the heating efficiency of the soil and the transfer rate of the chlorinated hydrocarbons across the membrane. Replacement membranes vary in their transport efficiency, and the porosity of a membrane changes with use. These attributes cannot be eliminated, so a procedure was needed that would standardize the Haloprobe logs and account for as many of these changes as possible.

Knowing that the mass transport efficiency for chlorinated hydrocarbons across the membrane is never static, it is concluded that any attempt to calibrate the Haloprobe for use as an analytically accurate and precise predictor of downhole-chlorinated concentrations is impossible. This does not prevent the Haloprobe from being used as an excellent screening tool. Even though the drift is sufficient to prevent analytical results, the detector's response does scale accurately with chlorinated solvents moving across the MIP. Therefore, the HaloProbe response is normalized for drift in sensitivity and baseline, but a full analytical calibration is not performed. Full dynamic range testing has been done in the lab to demonstrate linear response over the full range of concentrations expected to be encountered in the field, but field calibration is limited to a single point calibration that includes a single chlorinated hydrocarbon calibration sample.

DTI has conducted extensive research in developing artificial spiked soil samples and probe advancement emulation systems for determining the most appropriate calibration technique for MIP based measurements. This research has shown that consistent preparation of soil samples for calibration is virtually impossible because of variability in water content, sample mixing, volatile loss, sample presentation to the MIP, etc. These problems have led to the use of a flowing water solution to mimic the advancement of the MIP through the subsurface. This method was chosen because it closely simulates the membrane movement and exposure to saturated soil, which in practice, also flows continuously over the MIP.

The approach that has been developed for calibrating the Haloprobe, referred to as the aliquot injection method, is as follows:

1) A flow cell as shown in Figure 2 is attached to the MIP membrane with a pair of customized Vise Grips.

2) A 5 mL aliquot of calibration solution which can be 1 ppm or 10 ppm TCE is injected into the flow cell. In the Rickenbacker work 1 ppm was used for pushes 1 through 3 and 10 ppm was used for the remainder of the pushes.

3) As soon as signal levels reach their maximum, a pulse of compressed air is blown through the cell to quickly clean out the system.

4) Signal levels are then allowed to return to baseline at which time two more replicate injections are made to produce a total of three calibration signals.

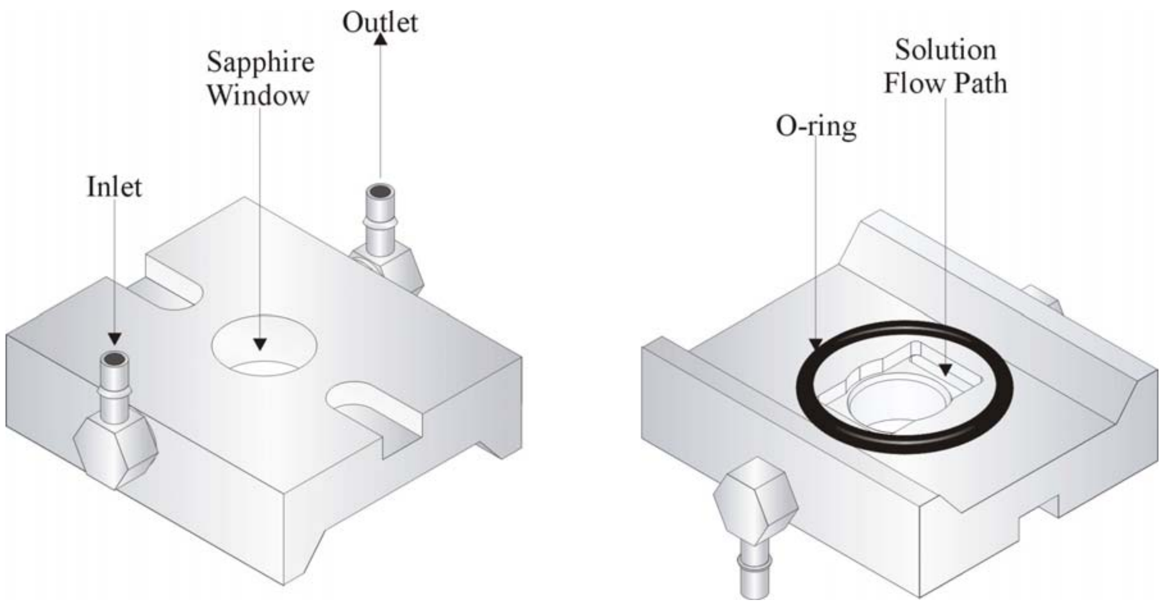


Figure 2. Schematic of the flow cell used to calibrate the Haloprobe

<u>In situ measurement procedure for Haloprobe system</u>

The following procedure was used for all of in situ Haloprobe measurements. First, both the detector and MIP temperatures were checked to insure that they were at stable operating temperatures; 130 ºC for the MIP and 1020 ºC for the detector). Next, the MIP membrane was placed at ground surface and the CPT data acquisition program was zeroed. The data acquisition program was started and the probe was advanced at a rate of 2 cm/sec (approximately 4 feet per minute). The probe advancement was continued until either the maximum investigation depth was achieved or the probe met push refusal. The investigation depth was based on information provided by Shaw Environmental. When each push ended, the data file name was recorded, and the data file was saved to the hard drive.

<u>Extraction procedure for Haloprobe system</u>

At the end of the push the probe was extracted from the subsurface while the MIP and detector were still operating to maintain sufficient temperature to minimize water condensing in the transfer line between the MIP and detector. Upon extraction, the MIP

was cleaned off with paper towels, washed with distilled water, and visually inspected for membrane damage.

Data Processing

Data normalization process

Once DTI personnel were back in Fargo, the calibration logs were used to change the raw Haloprobe logs from voltages to total halogen concentrations. The calibration runs collected prior to each in situ measurement were used to normalize the subsequent Haloprobe data log. First, each calibration was corrected for background by subtracting the average baseline signal collected at the start of the run. Next, the peak height for each injection of standard was calculated by finding the maximum value over each peak. The maximum values were averaged to determine a mean value for that calibration run.

The lack of speciation between chlorinated VOCs with the Haloprobe detector raises an aspect of the calibration procedure that must be explained. The Haloprobe detector responds to the number of halogens in solution so this must be taken into account when doing the analysis. For example, if two equal concentration solutions were prepared, one containing TCE and the other PCE, the signal level from the PCE solution would be 4/3 that of the TCE solution. Therefore, one cannot simply plot the solution concentration but must rather plot the total halogen concentration. The total halogen concentration for a given analyte is determined by multiplying the solution concentration by the number of halogens on that analyte; 2 for cis-DCE, 3 for TCE, 4 for PCE, etc. Therefore, for the calibration runs performed during this demonstration the total halogen concentrations would be:

For pushes 1 through 3:

1 ppm TCE x 3 halogens = 3 ppm total halogen concentration

For remainder of pushes:

10 ppm TCE x 3 halogens = 30 ppm total halogen concentration

To convert in situ measurements to a total halogen concentration, the logs were first corrected for background using the average baseline signal collected at the start of the run. The appropriate correction factor and the total halogen concentration of the calibration solutions, 3 ppm halogens for Pushes 1-3 and 30 ppm halogens for remainder of pushes, were then applied to each in-situ measurement.

Data interpretation

In order to facilitate the data interpretation, the site was split into three areas (Figure 3). By doing this, each of the areas could be more easily represented by a transect of the pushes conducted at that area. For area 1, it was necessary to use three different transects to fully evaluate the area.

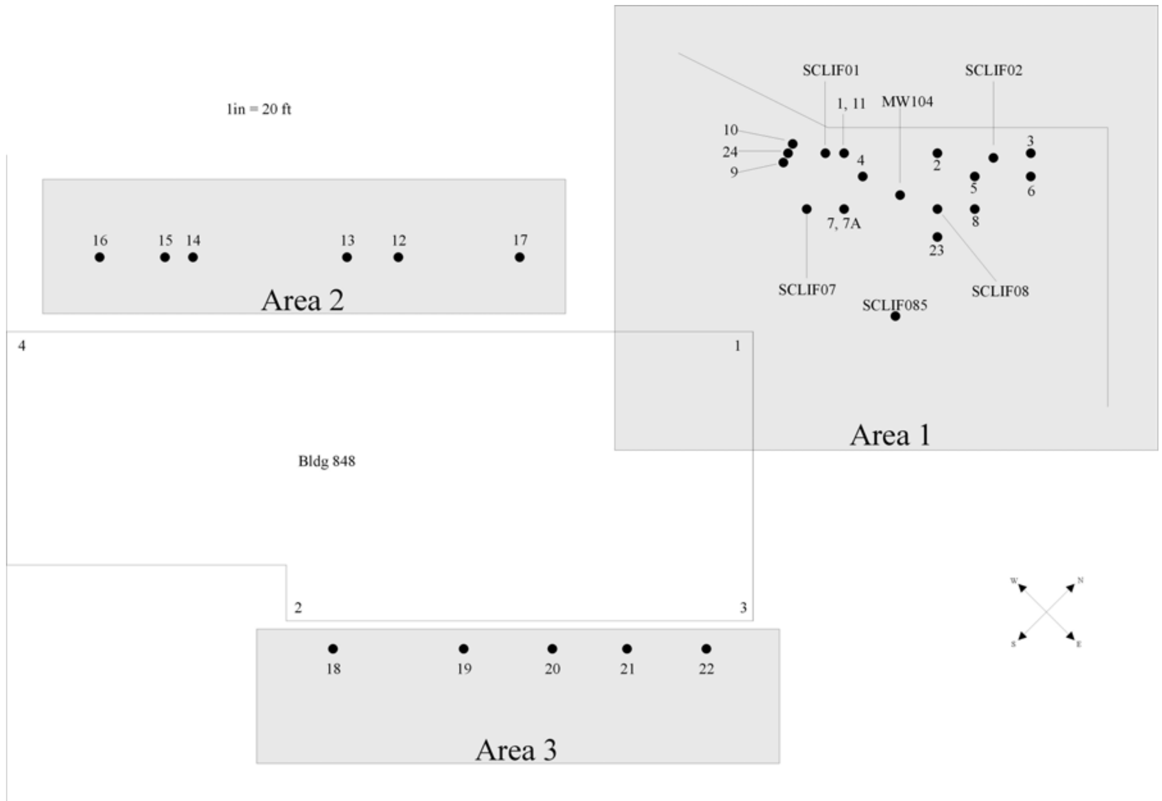


Figure 3. Building 848 site, Rickenbacker IAP, OH

<u>Area 1</u>
The pushes done in area 1 (near MW104) showed most contamination to be just SSW of MW104 (Figures 4, 5, and 6). Pushes at two adjacent locations 07 , and 07A had the highest concentrations of halogenated compounds. However, the area of contamination seems to be localized to within a few feet of these pushes since pushes to the south and north had no detectable chlorinated compounds. Several replicate pushes were done; 1 and 11, 7 and 7A, 9, 10 and 24. There was good agreement between 7 and 7A, and among 9, 10 and 24, however pushes 1 and 11 did not have good agreement. This discrepancy may be due to problems discussed previously with the MIP. An interesting feature of pushes 3, 4, 5, and 6 was the baseline decrease in the middle of the push. Currently it is unclear what type of phenomenon would cause a signal decrease in the Haloprobe system

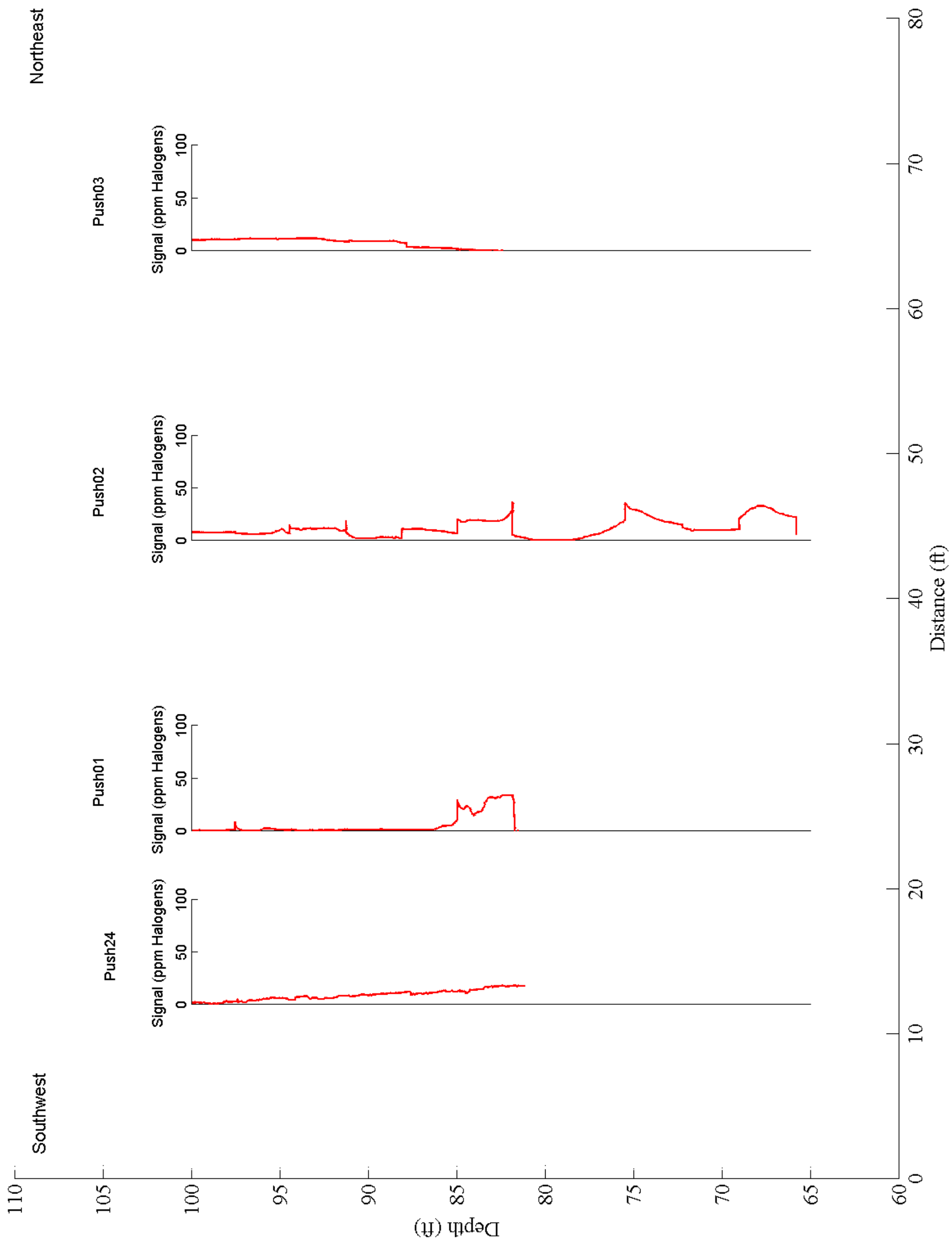


Figure 4. Area 1 transect 1 (concentration scale: 200 ppm Halogens)

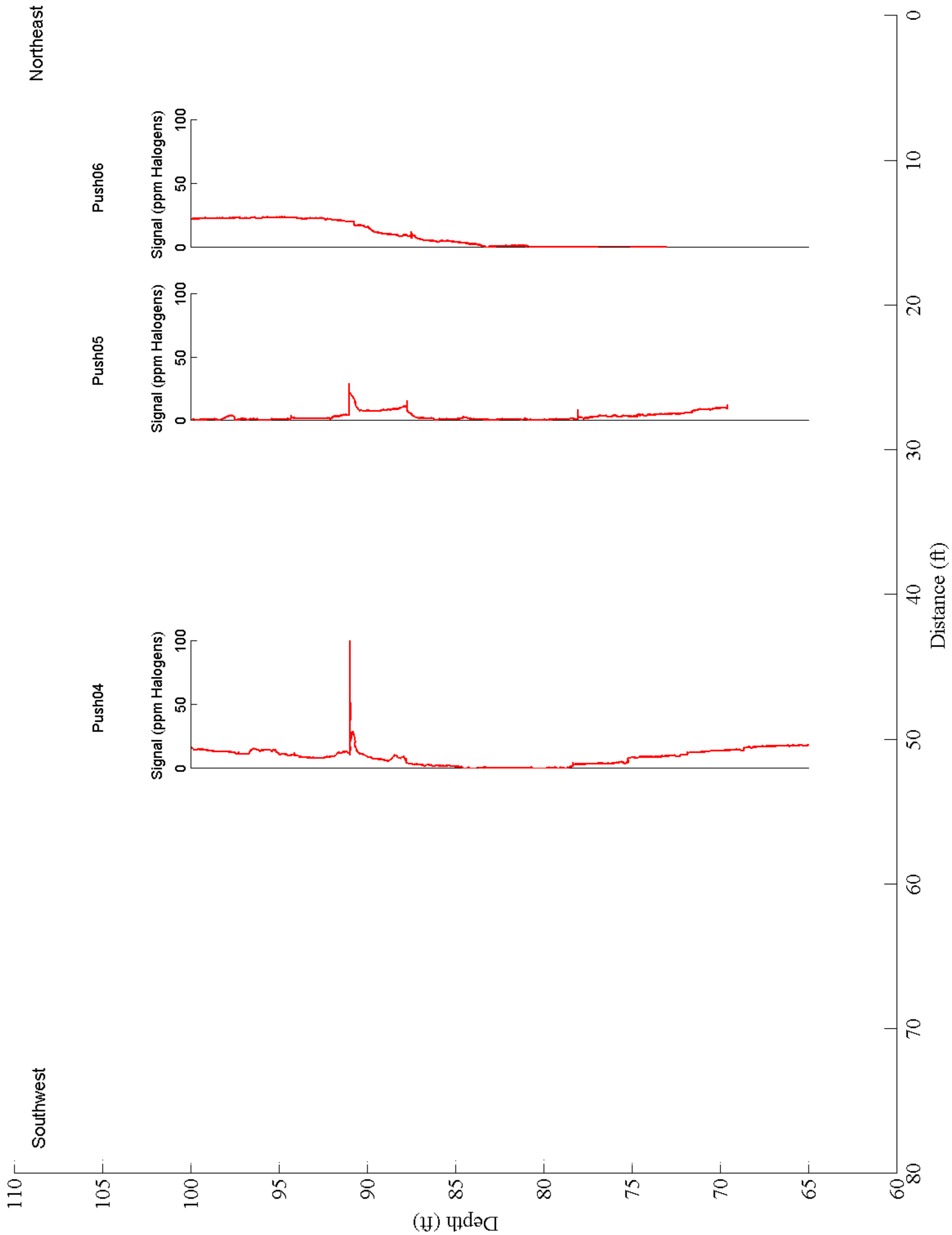


Figure 5. Area 1 transect 2 (concentration scale: 200 ppm Halogens)

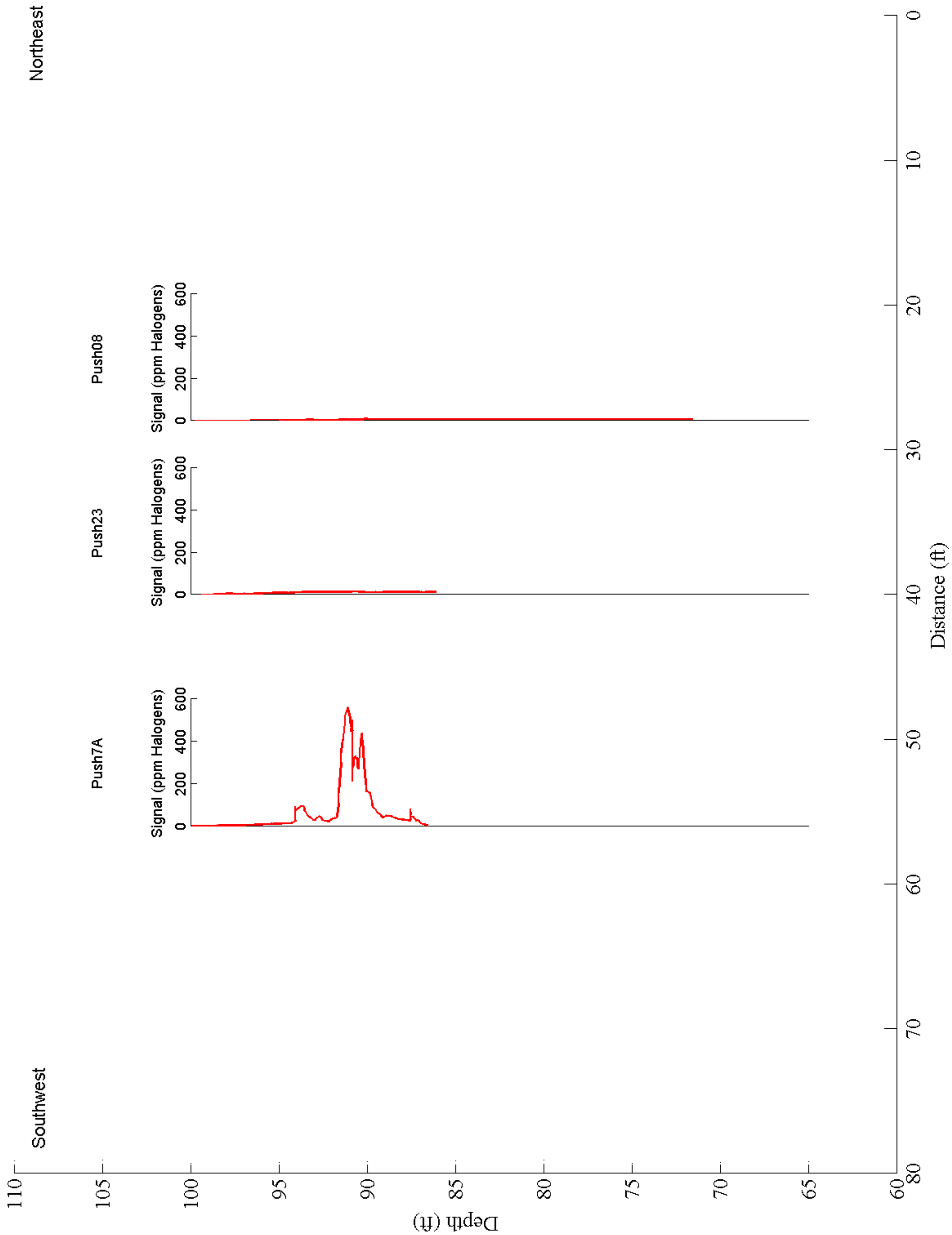


Figure 6. Area 1 transect 3 (concentration scale: 600 ppm Halogens)

Area 2

Area 2 transect in Figure 7 lies along the Northwest side of building 848. The greatest amount of contamination was noted at push locations 17, 14, and 15 with lesser contamination at location 12. The most heavily impacted area was push location 17

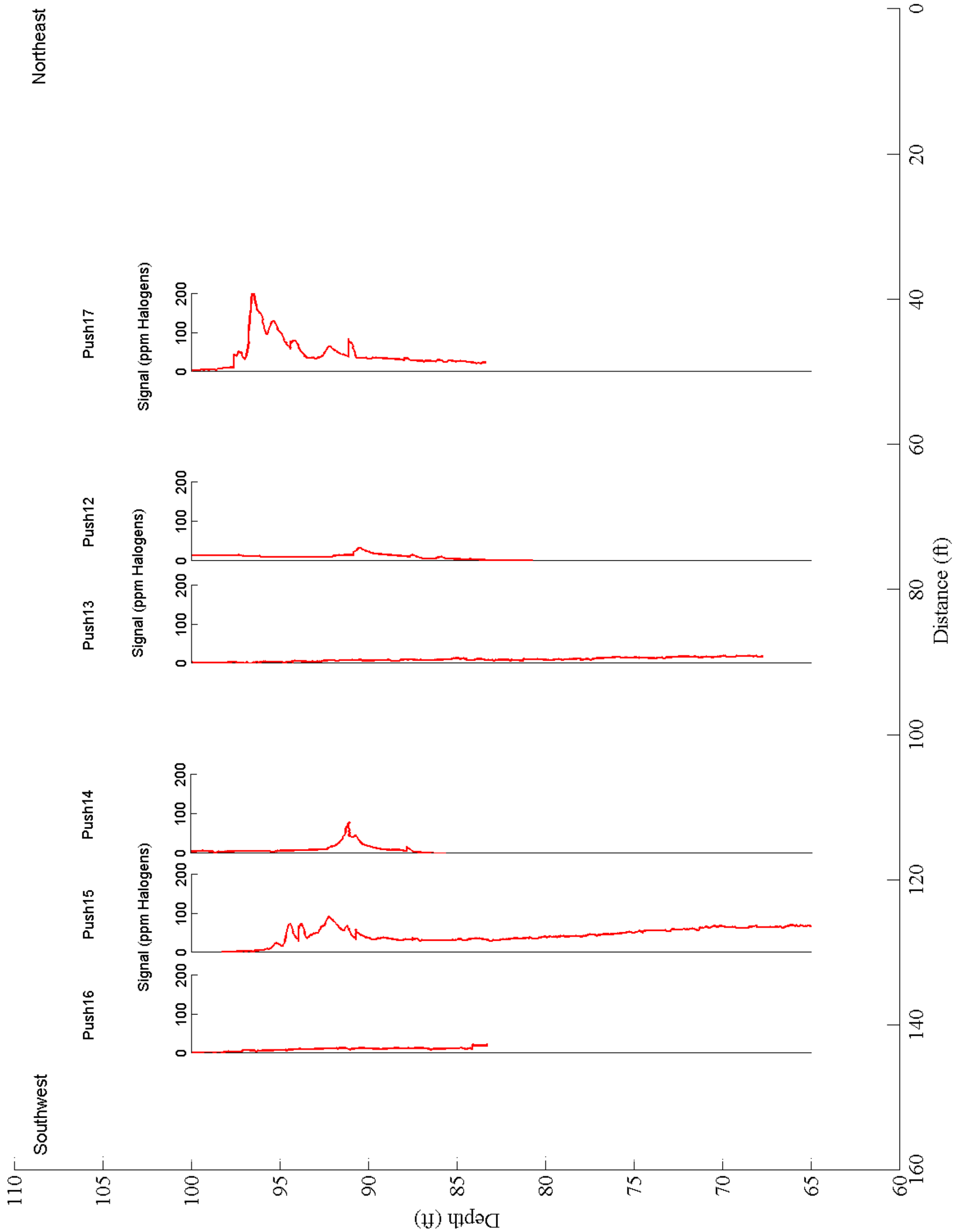


Figure 7. Area 2 transect 1 (concentration scale: 200 ppm Halogens)

Area 3

The Area 3 transect shown in Figure 8, along the Southeast side of building 848 had low levels of contamination at three of the push locations (20, 21, and 22). Signal increases in pushes 18 and 19 are indicative of baseline drift rather than actual contamination. This is evidenced by the change in the signal levels at rod breaks rather than during actual probe movement. An interesting feature of the logs in this area is the amorphous shape of the logs. It is unclear whether this shape is due to a low concentration, homogeneous distribution through the soil or from system drift.

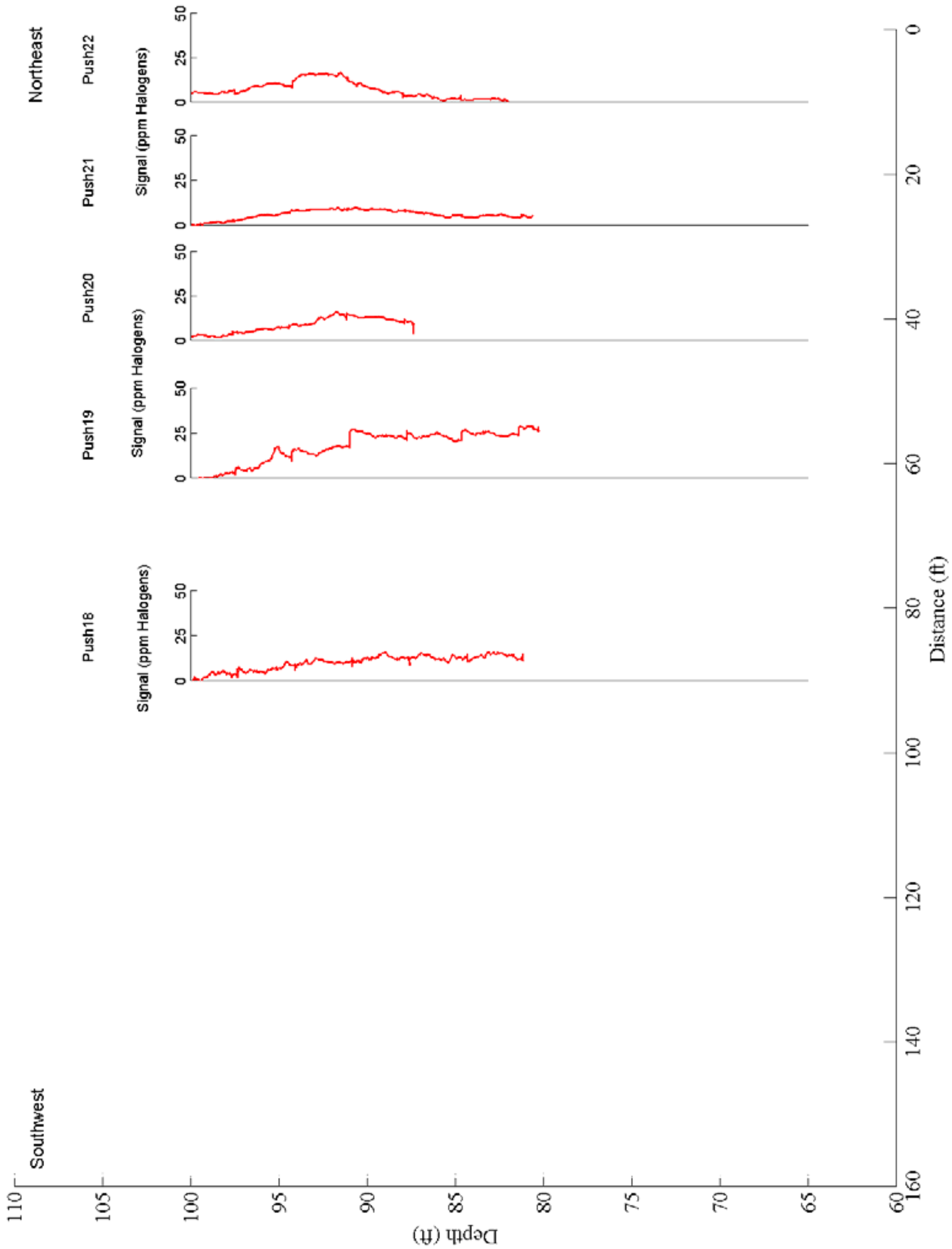


Figure 8. Area 3 transect 1 (concentration scale: 50 ppm Halogens)

Equipment Performance

The field performance of the Haloprobe system was the primary focus of this work. In general the fieldwork was successful, demonstrating that DTI's Haloprobe system can be used for delineating subsurface chlorinated hydrocarbon contamination.

During the Haloprobe work the field team experienced a few problems with the hardware. The following is a list of problems encountered and steps taken to resolve the problem.

Problem	Resolution
Saturated detector during first push	Lowered gain setting to bring signal back on-scale. This is an issue for the operator since the gain setting does not affect the data collection.
High background signal noted after end of first push	Increased flow rate and allowed baseline to drop and become stable. However, did not allow baseline to come back to original level.
No carrier gas flow rate display	Ordered flow controller and flow meter with LCD displays. Electronically controlled flow meter and controller should be purchased for the system
Sensitivity of MIP decreased drastically from pushes 1 to 3. Calibration solution no longer gave adequate signal levels	Changed calibration solution concentration from 1 ppm (3 ppm total halogen concentration) to 10 ppm (30 ppm total halogen concentration) after push
No signal detected during replicate push at Push 01 location.	Replaced MIP block.

The Haloprobe system generally performed well throughout the field work. Two main problems were encountered during the demonstration. First, the MIP block failed at the end of the first day of work. This failure was compounded by the fact that the wrong replacement blocks had been sent to KCD. Upon receipt of the correct blocks, work was resumed without incident.

The second problem was the inability to actively monitor the flow rate of the carrier gas using the commercial Geoprobe MIP controller. Without this capability, the diagnosis of the problems encountered on the first and second days was much more difficult. To alleviate this problem, a flow controller and flow meter were sent from DTI's facilities for use during the rest of the demonstration.

Recommendations

The gas handling system for the Haloprobe system could be improved to enhance user friendliness. While the manual mass flow controller supplied with the Geoprobe MIP controller works, electronic flow controllers would provide more precise adjustment capabilities and a user friendly display.

A mass flow meter should be incorporated at the end of the carrier gas return line (exhaust). This would allow the user to immediately know if a problem in the flow rate of the carrier gas had developed.

An improved water block should be incorporated on the probe. The current version uses a threaded ring to compress an o-ring around the umbilical cable. While this design works, the threaded ring is quite prone to cross threading. Furthermore, the specialized tightening tool is difficult to work with. DTI's water block design currently used for Geoprobe deployment should be modified and incorporated for the Haloprobe system. Due to the short service life of the MIP block, the block should be placed on top of the probe assembly, if possible. This change would allow for faster field repair and greatly reduce the risk of damaging the detector. The detector could then be sealed to prevent water infiltration from either the umbilical cord o-ring or the MIP to probe housing seal. An improved seal around the MIP block would be helpful. The SCAPS crew informed us that water leakage around the seal is the most common cause of failure on the MIP blocks.

Modify software to normalize data immediately rather than post processing with Excel spreadsheets. This software modification will allow the HaloProbe logs to be immediately compared with one another. The data file will contain both the raw data and normalized data.

Appendix

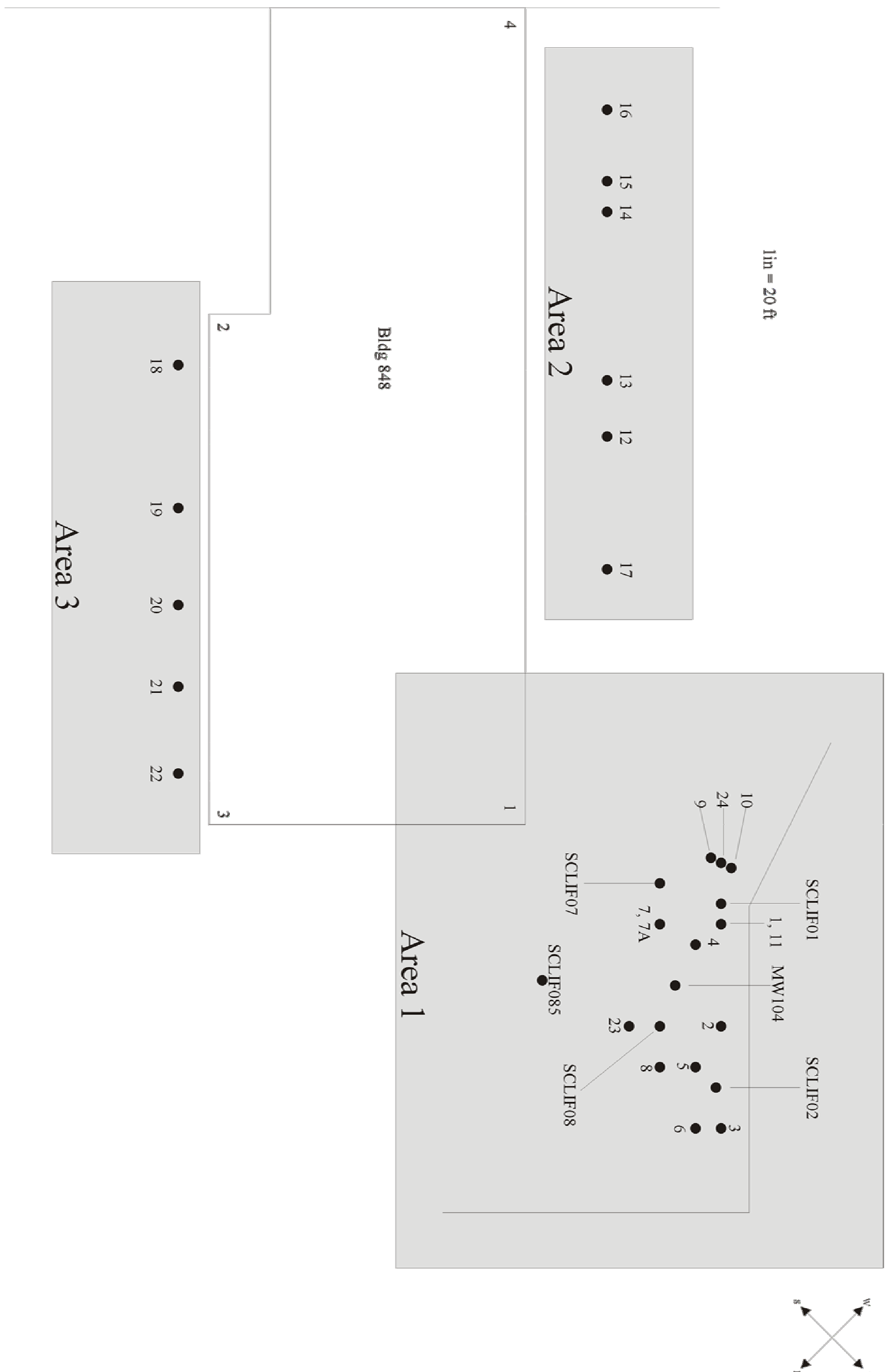
Appendix A is a compilation of data and maps for Rickenbacker IAP, OH:

- Site maps of Rickenbacker IAP
- Haloprobe logs in concentration
- LIF logs
- CPT soil classification

Acknowledgements

Many people played a role in the successful completion of this field demonstration. Mr. Jerry Hansen of Brooks AFB, TX was the project manager for this work and Mr. Alan Friedstrom of the Air Force Real Property Agency provided access and sponsorship to the site as well as assistance with utility clearance. The USACE Kansas City District provided the SCAPS truck and crew to execute the field work. Mr. Paul McCarren and Mr. Benjamin Uhl from Shaw Environmental provided area maps, access to the site, and assisted with planning of the field work.

APPENDIX A
Rickenbacker IAP Columbus, OH


1in = 20 ft
Area 1
Area 2
Area 3
Bldg 848
SCLIF01
SCLIF02
SCLIF07
SCLIF08
SCLIF085
MW104
1, 11
7, 7A
1
2
3
4
5
6
8
9
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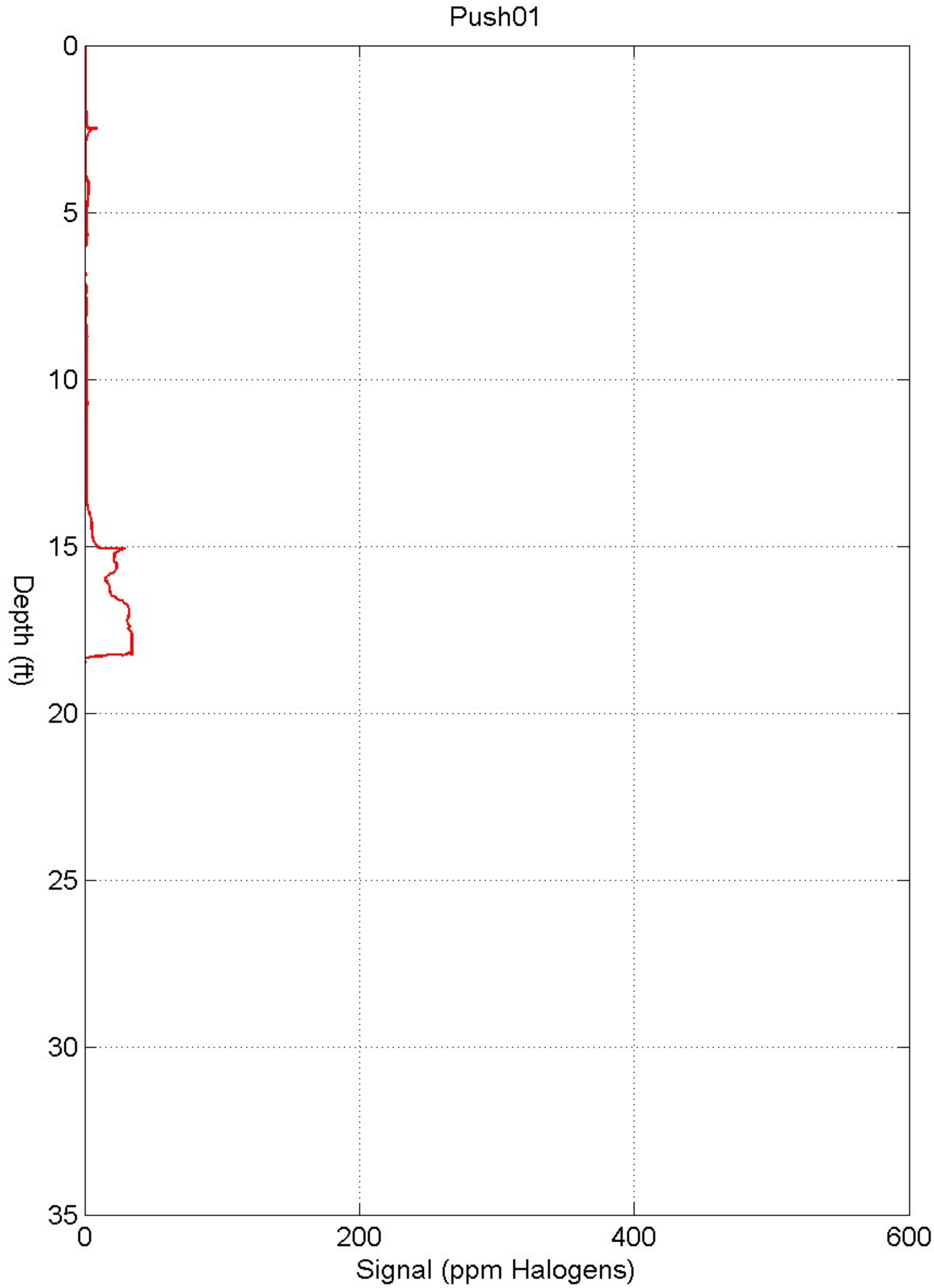
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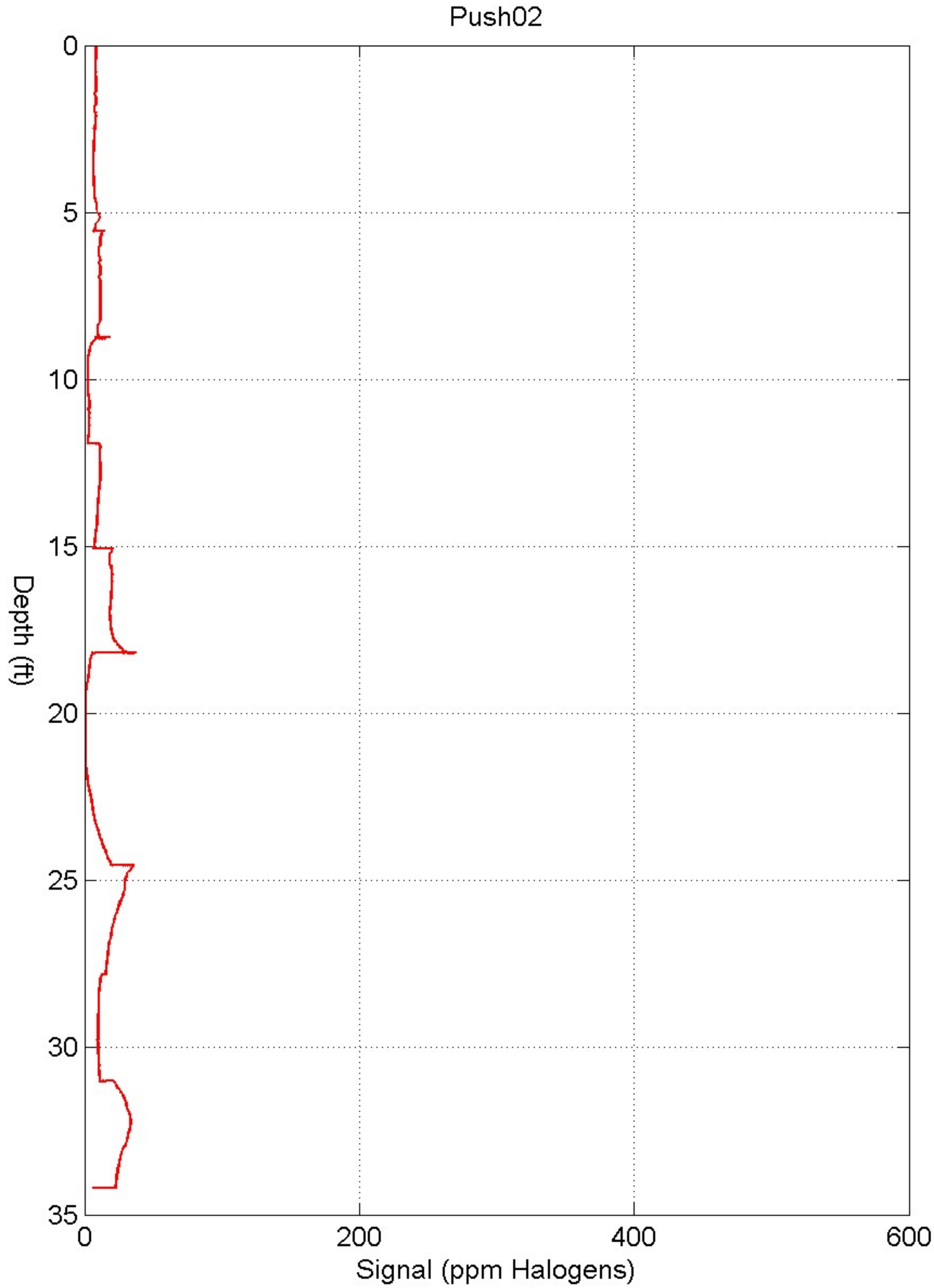
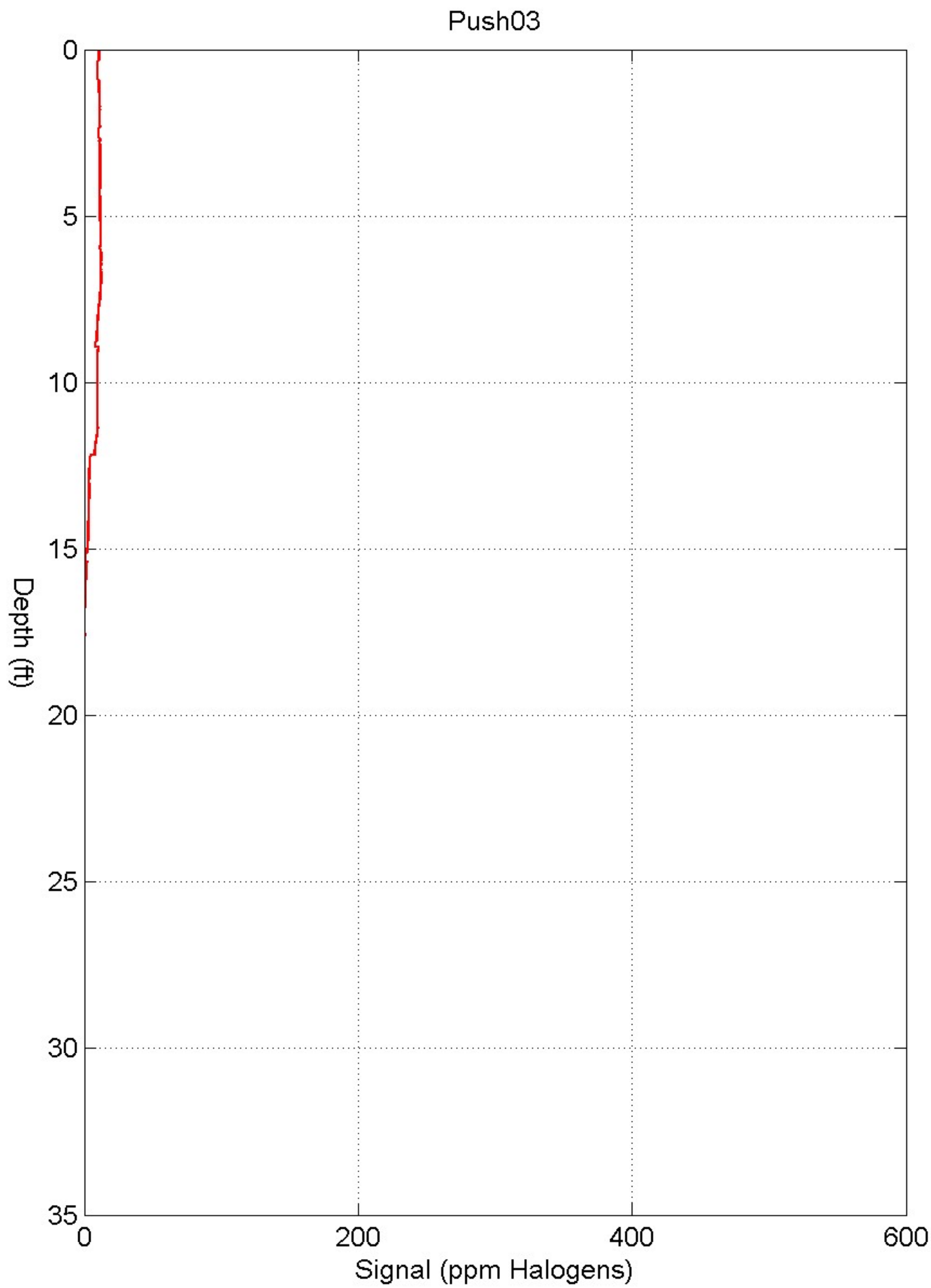
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)



Push02
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)



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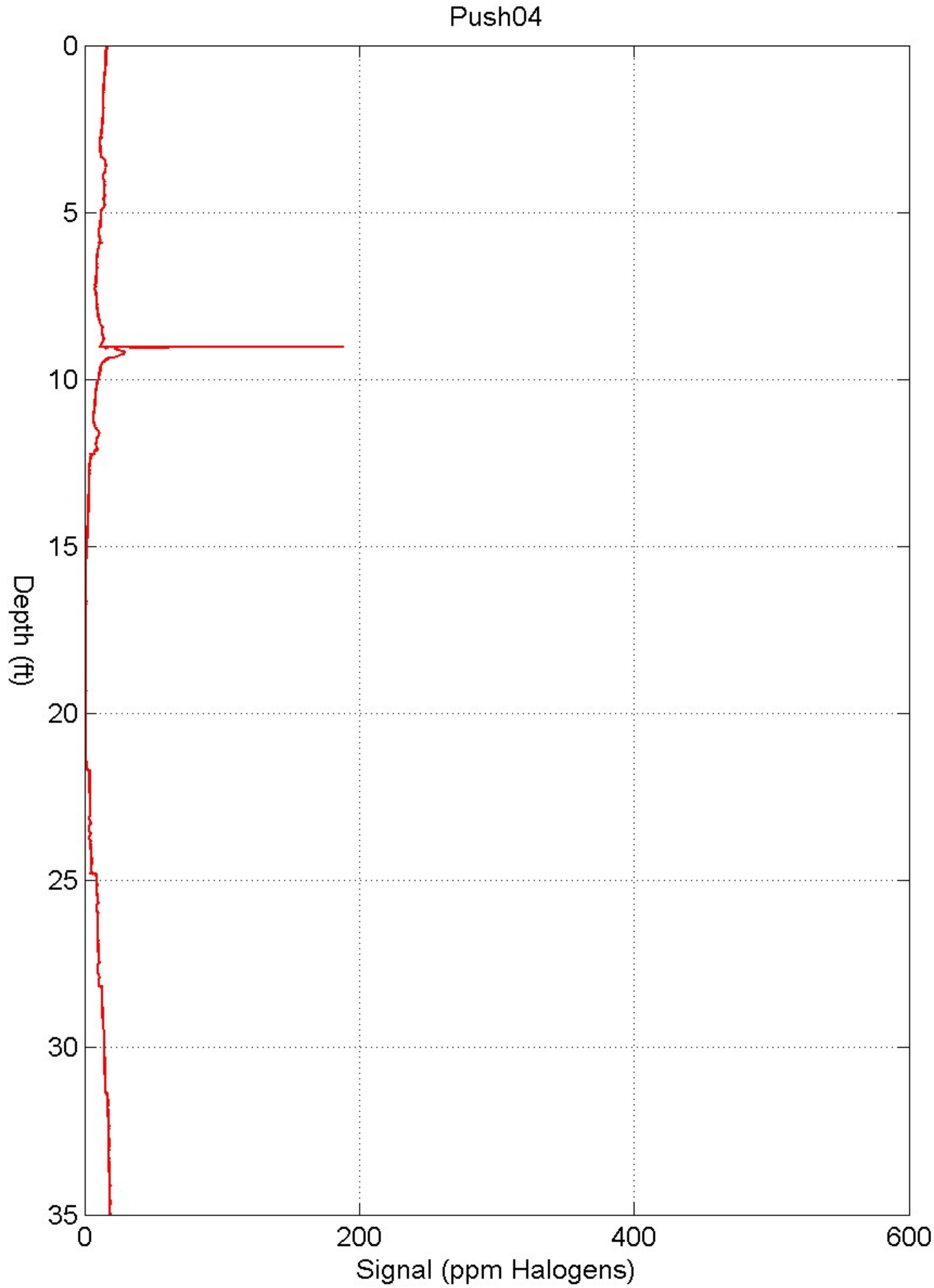
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)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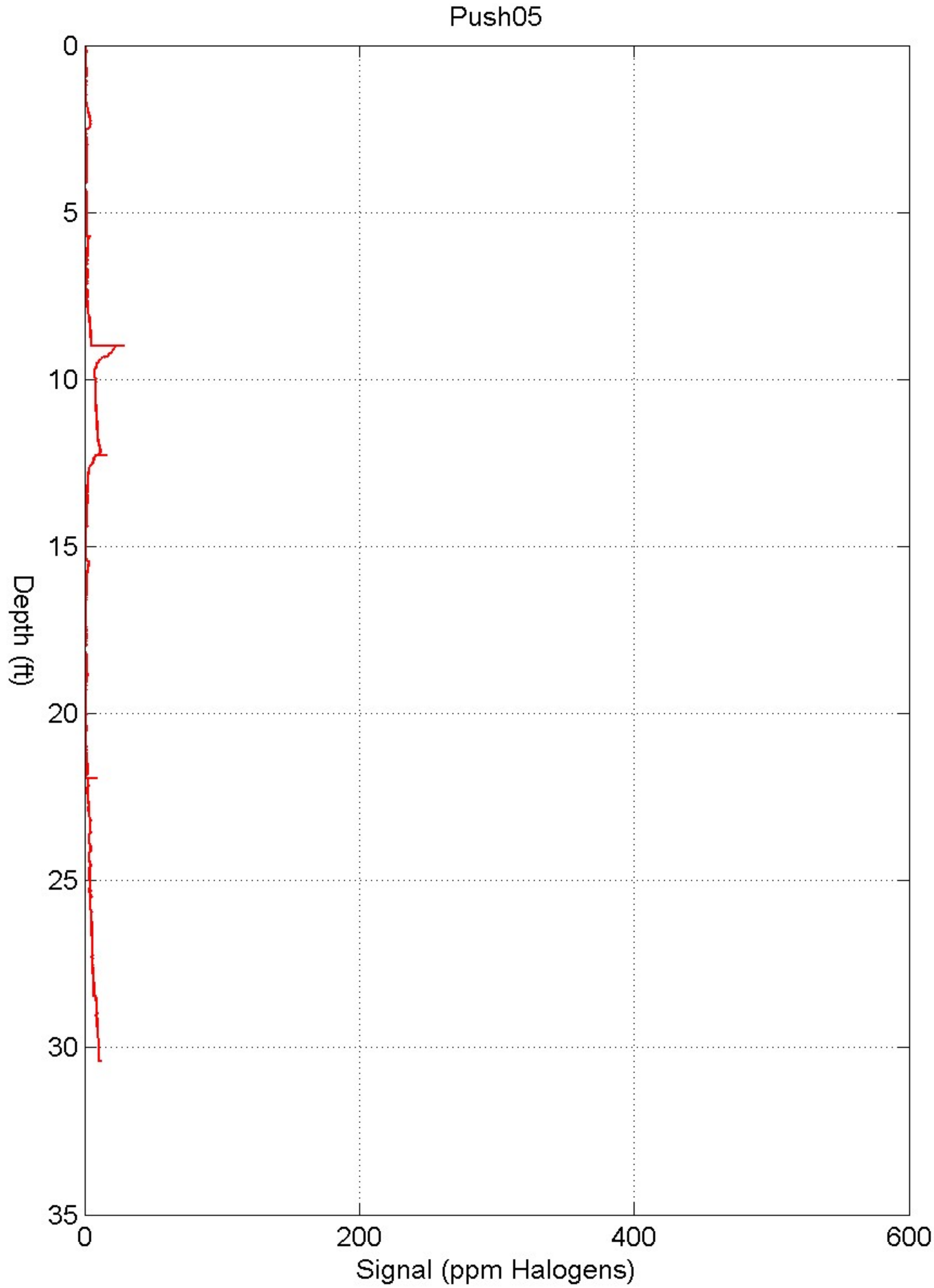
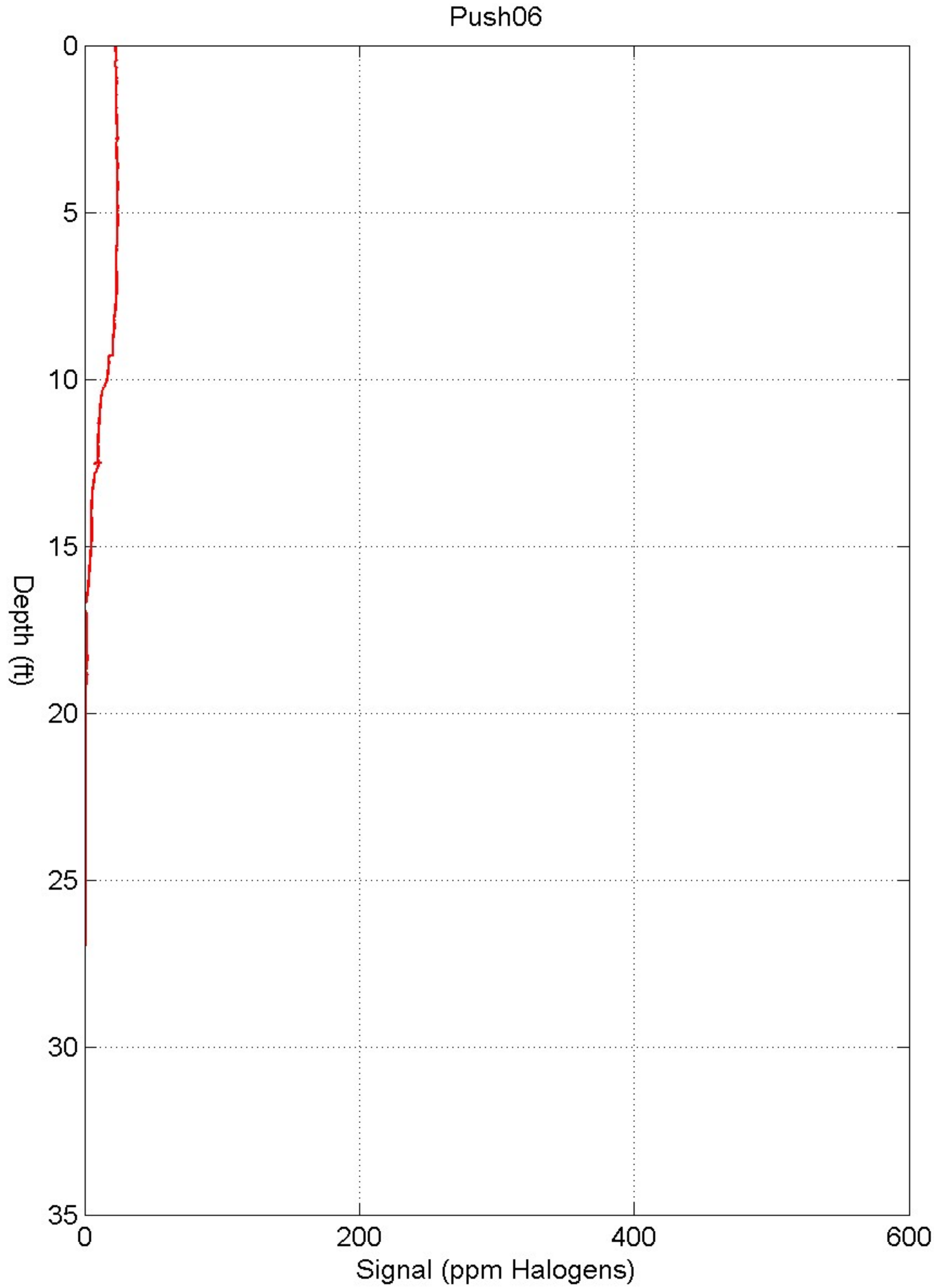
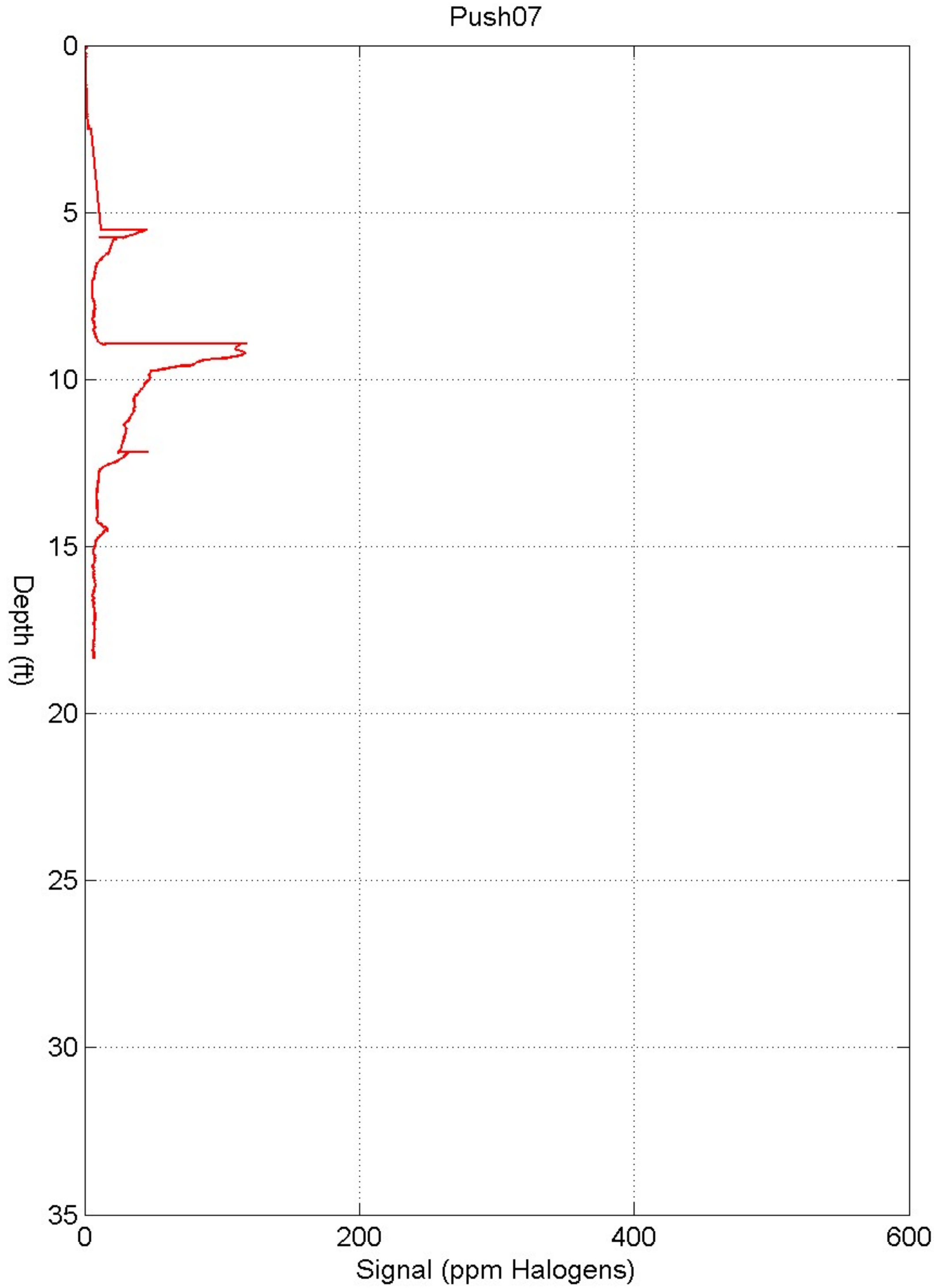
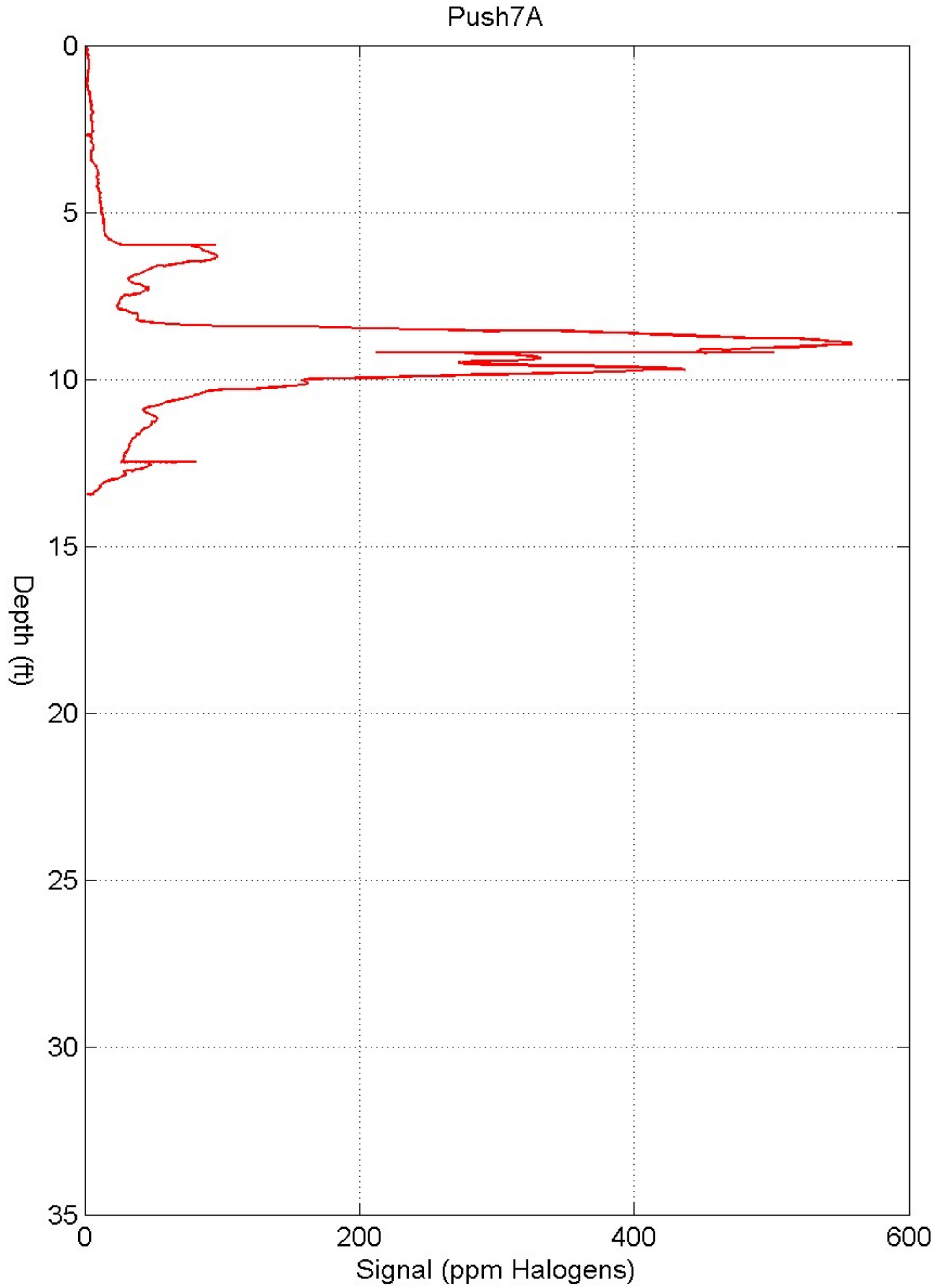
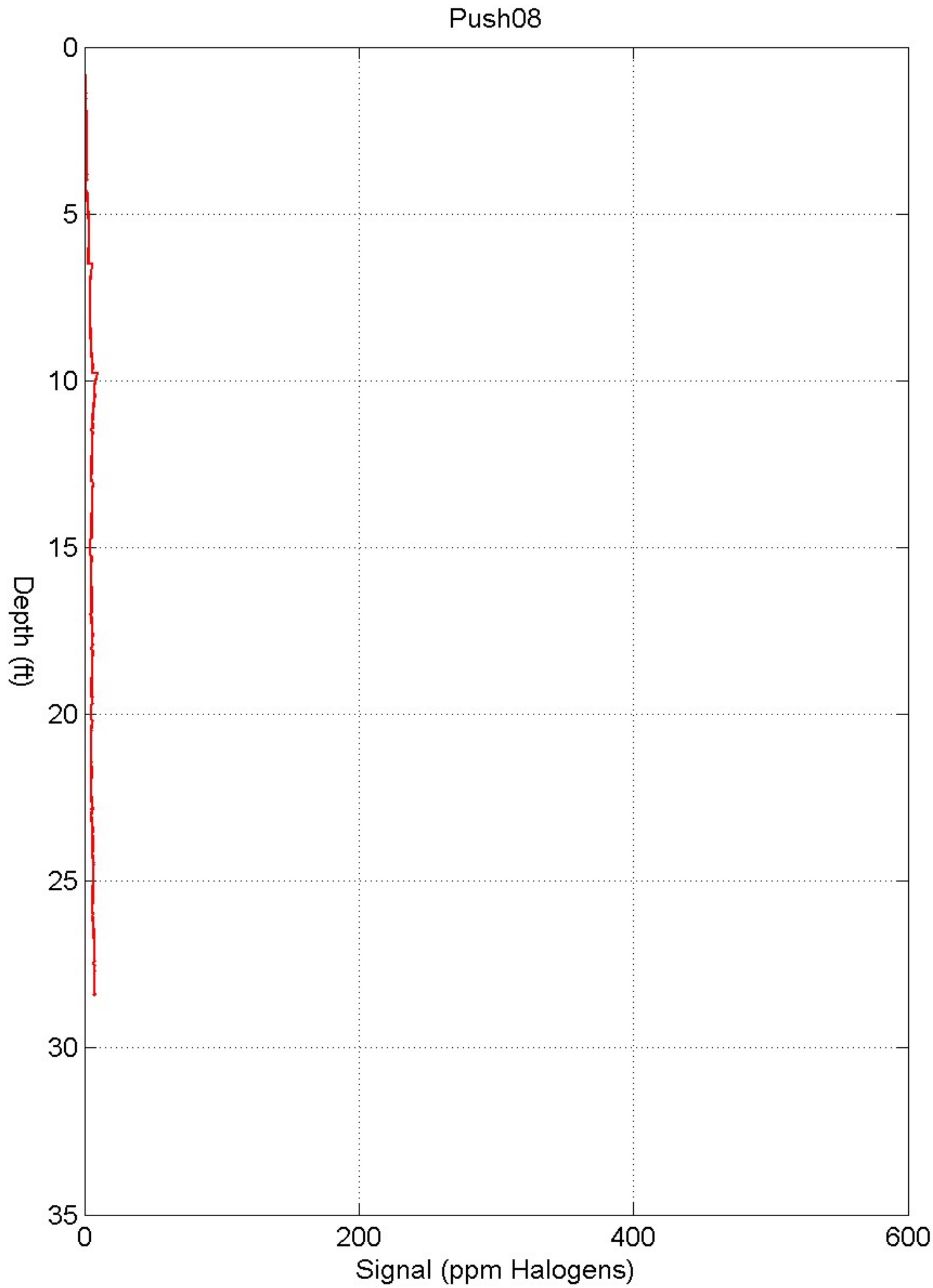
Depth (ft)
Signal (ppm Halogens)
0
5
10
15
20
25
30
35
0
200
400
600


Push05
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)

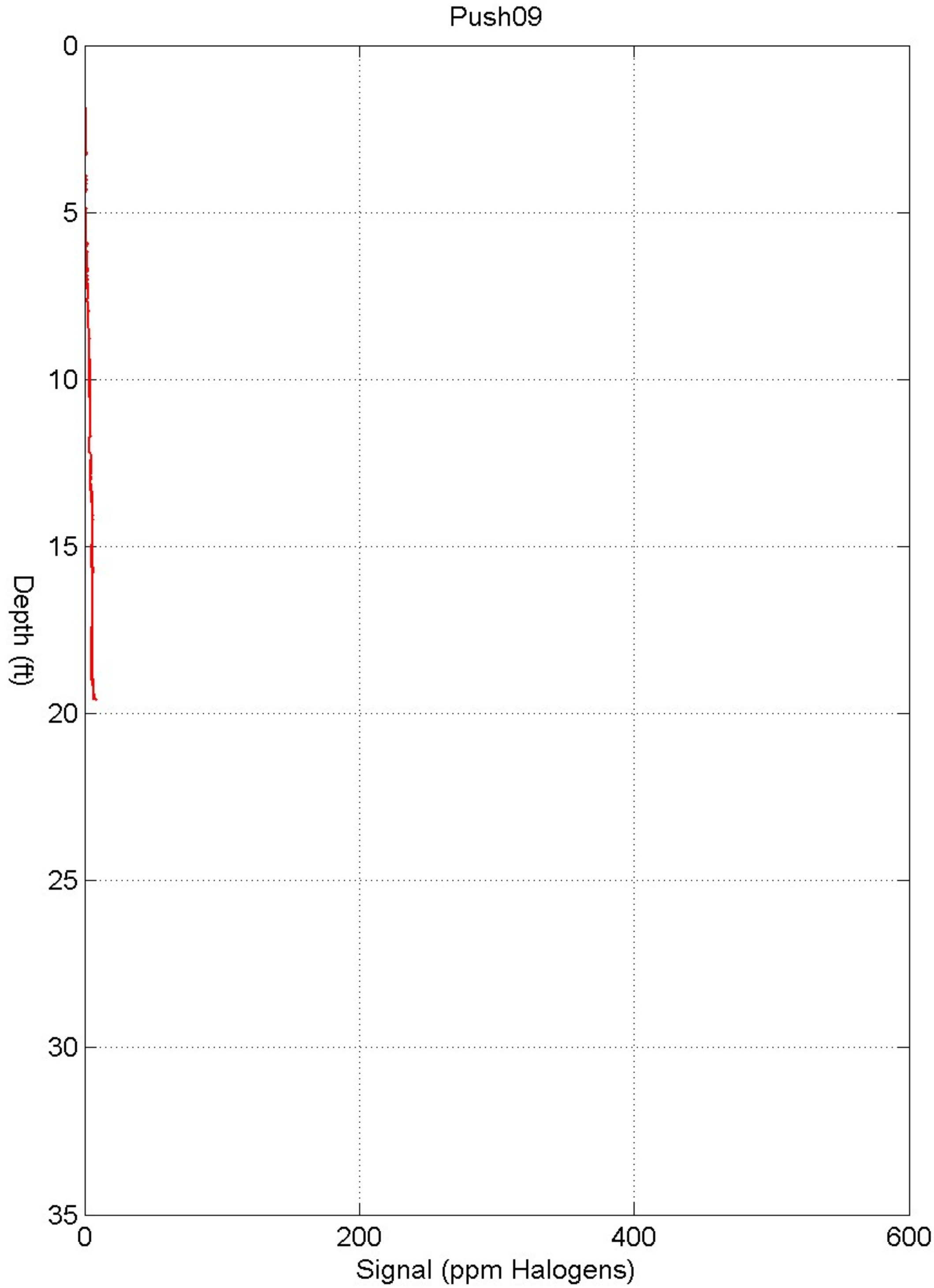

Push06
Depth (ft)
Signal (ppm Halogens)
0
5
10
15
20
25
30
35
0
200
400
600


Push07
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)

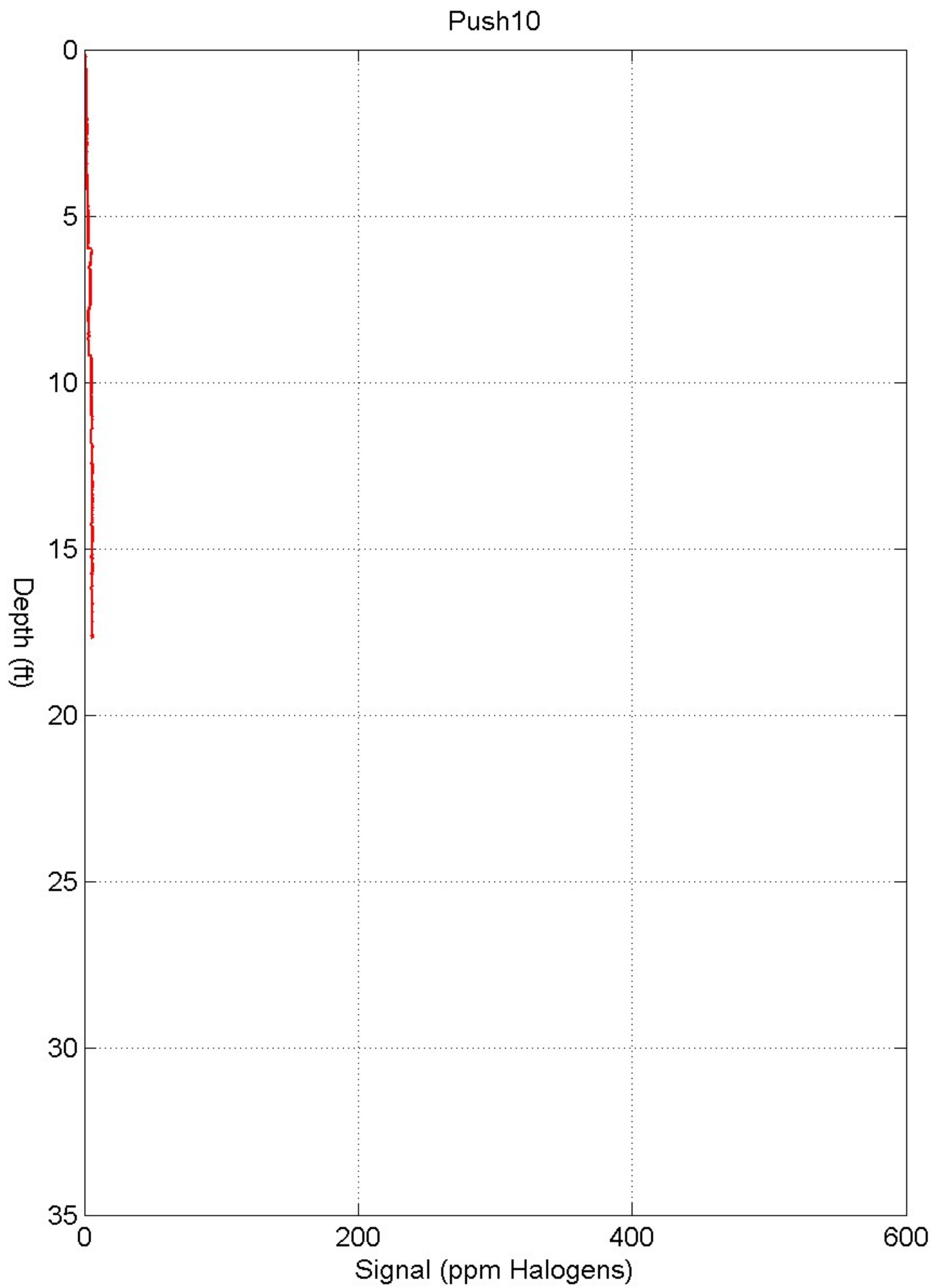

Push7A
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)

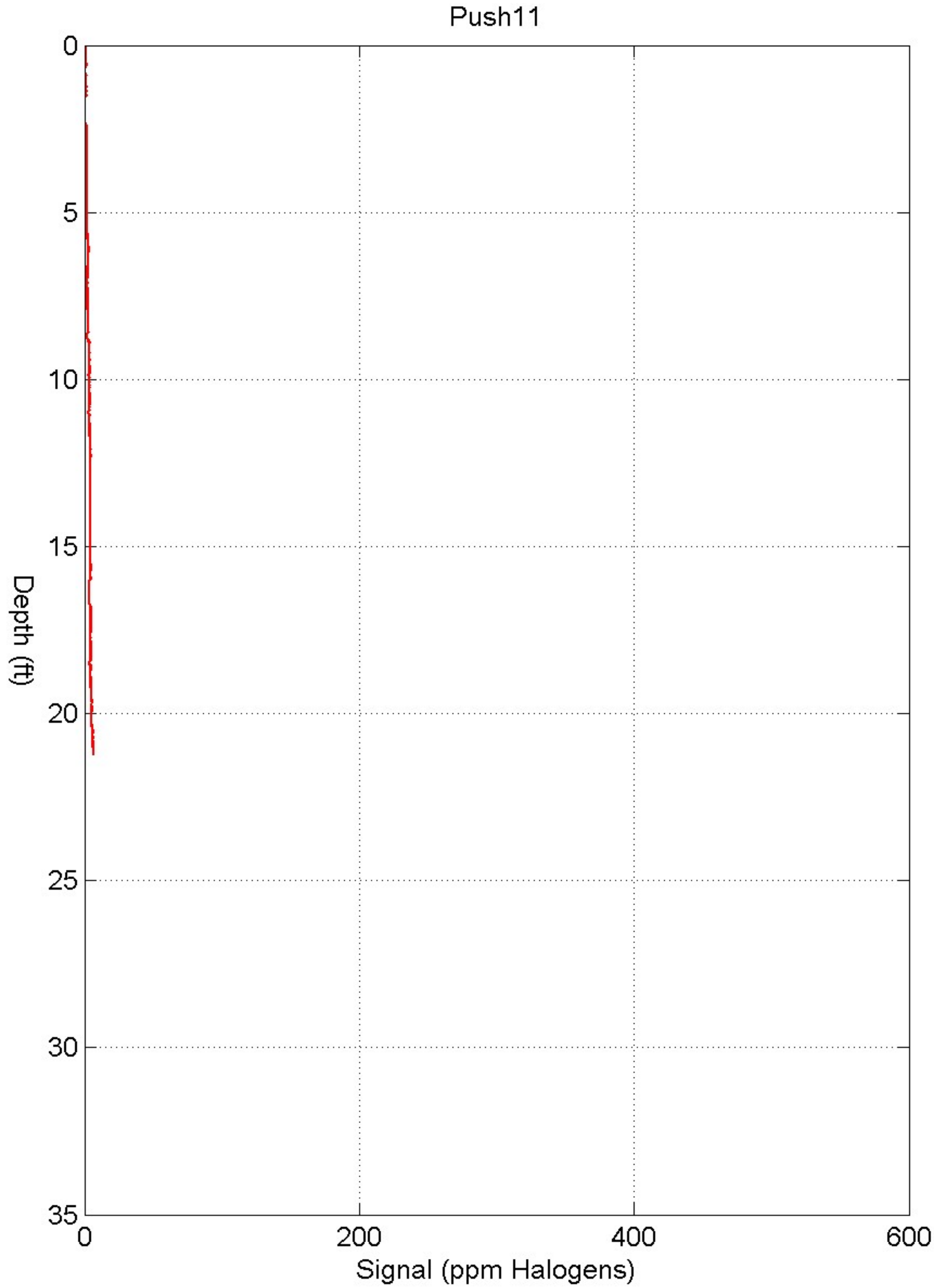


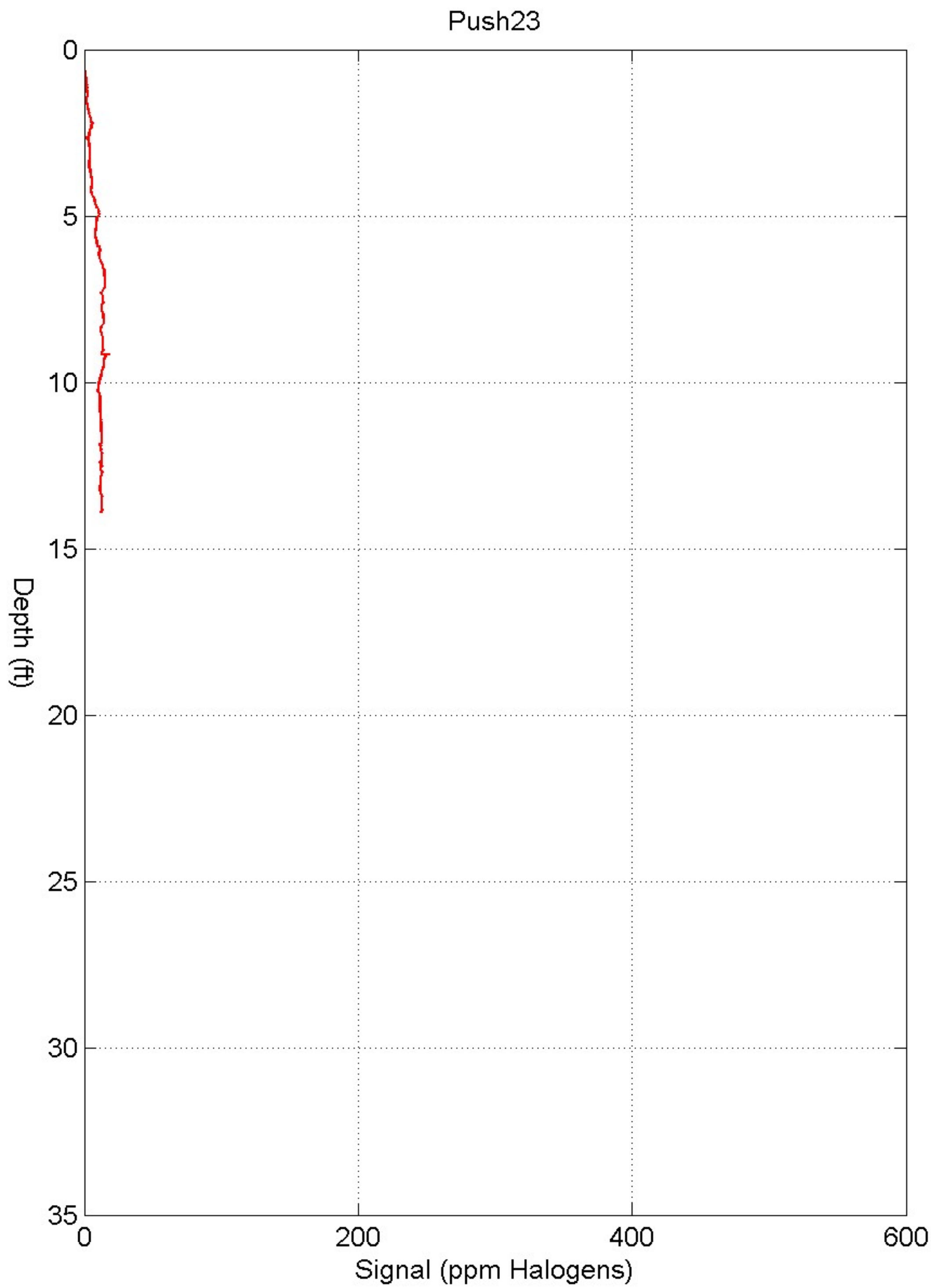
Push08
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)



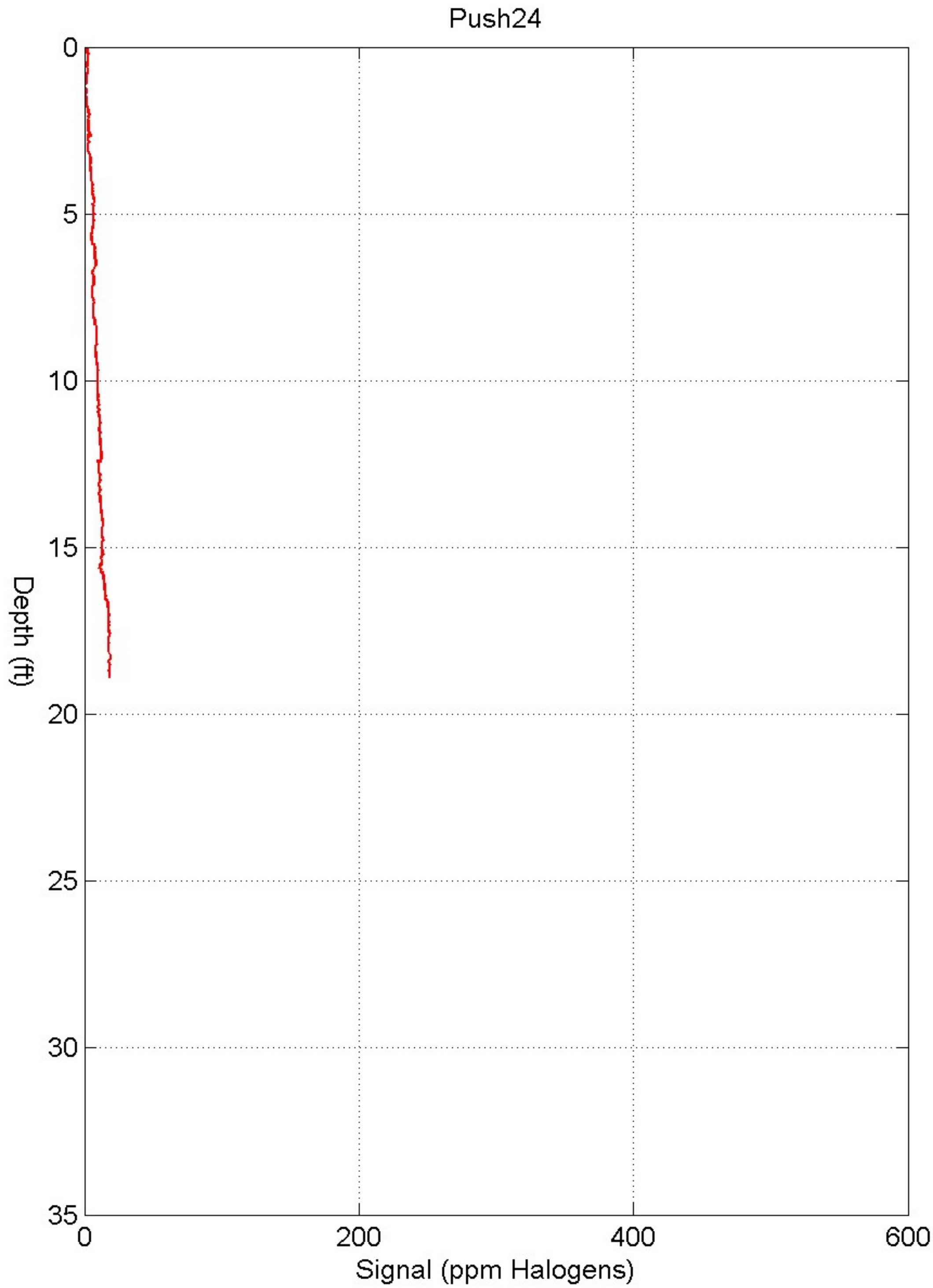
Push09
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)


Push10
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)

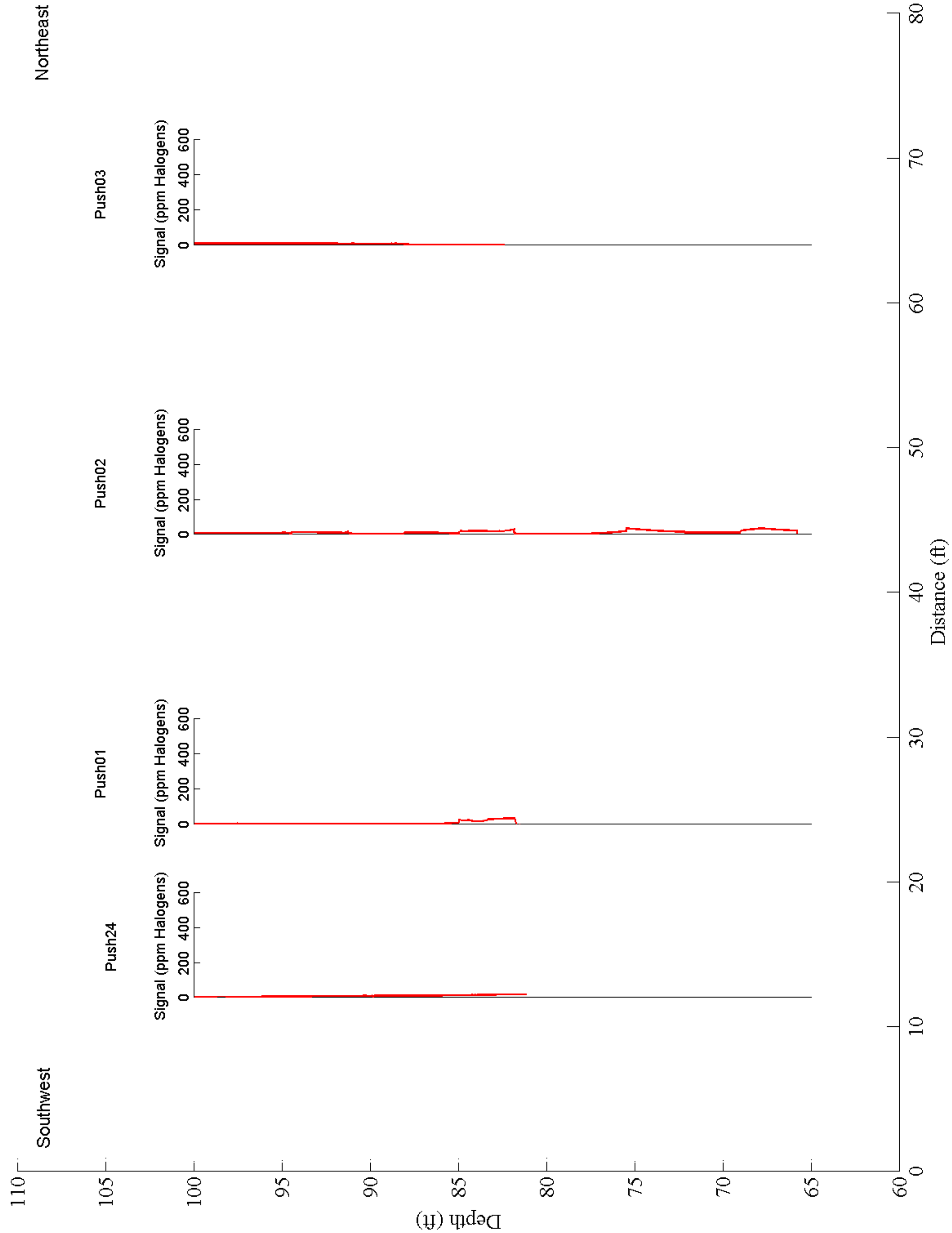

Push11
Depth (ft)
0
5
10
15
20
25
30
35
0
200
400
600
Signal (ppm Halogens)

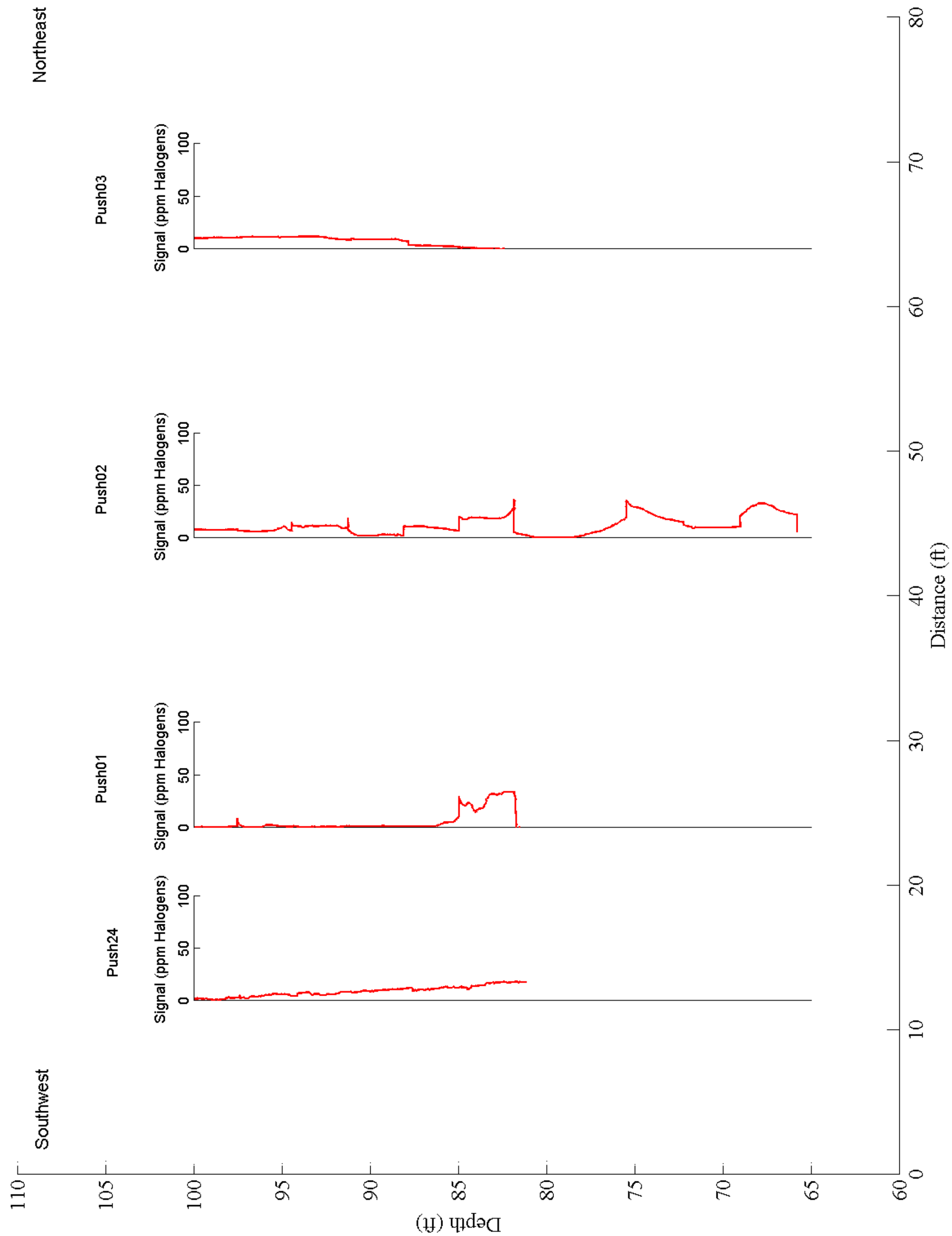


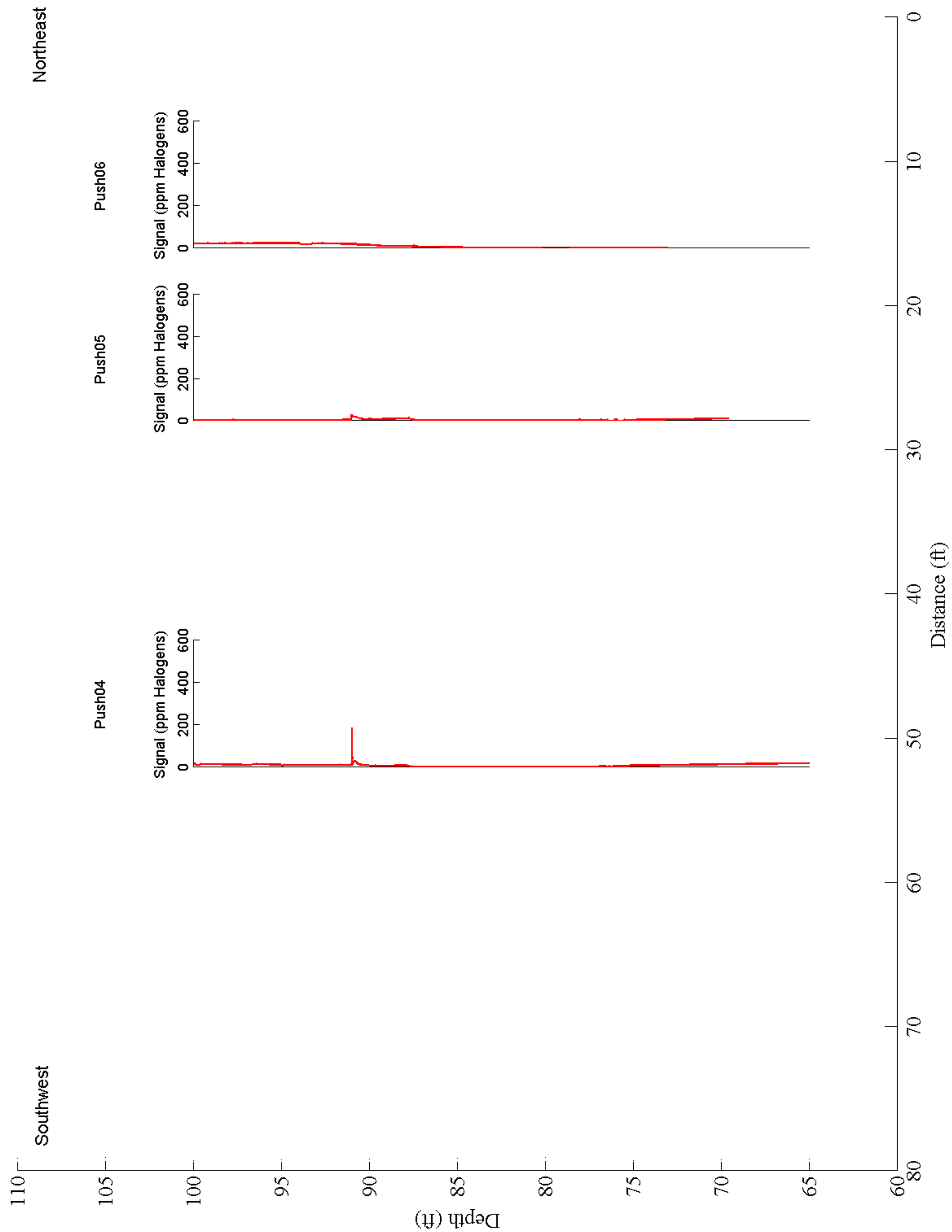
Push23
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)

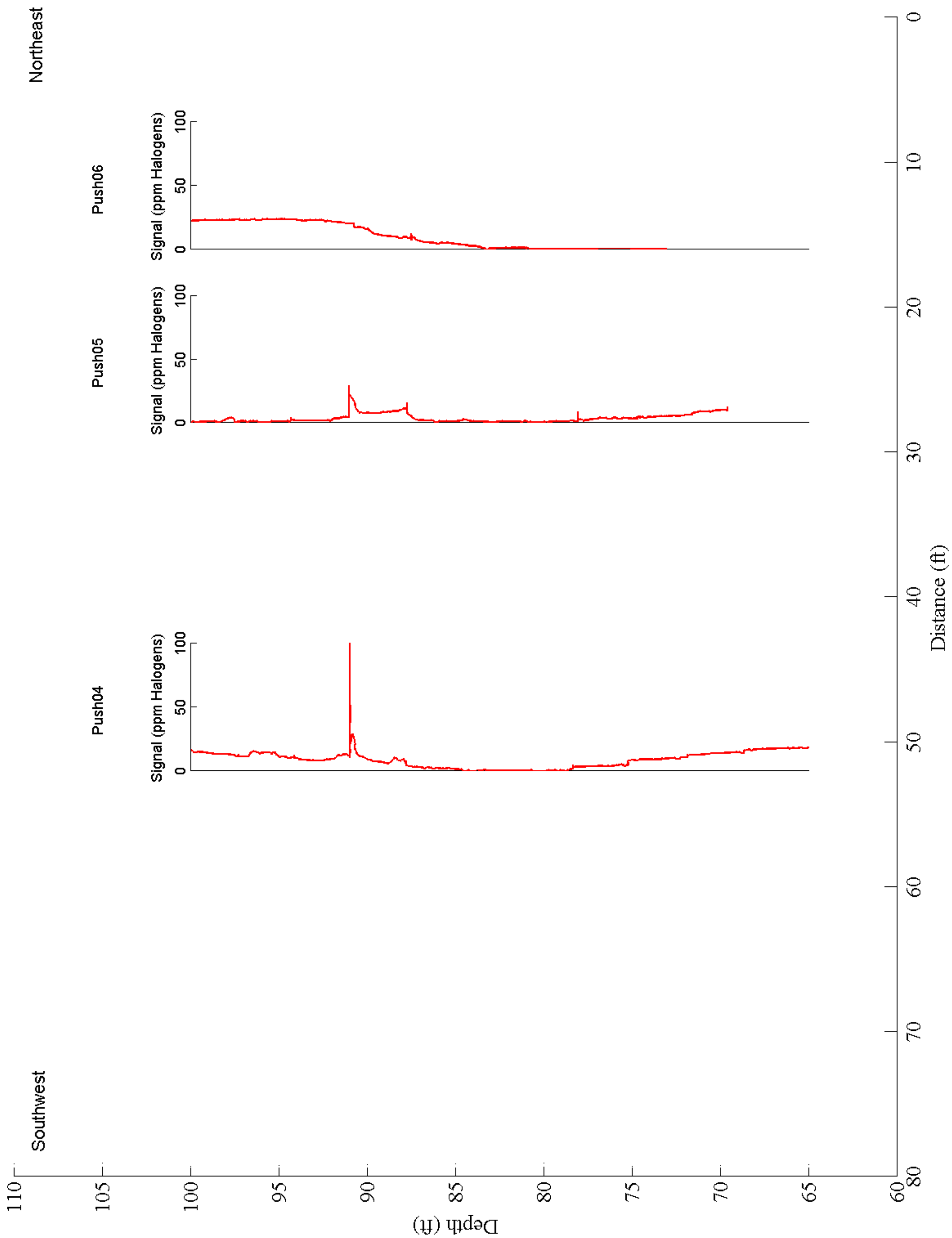


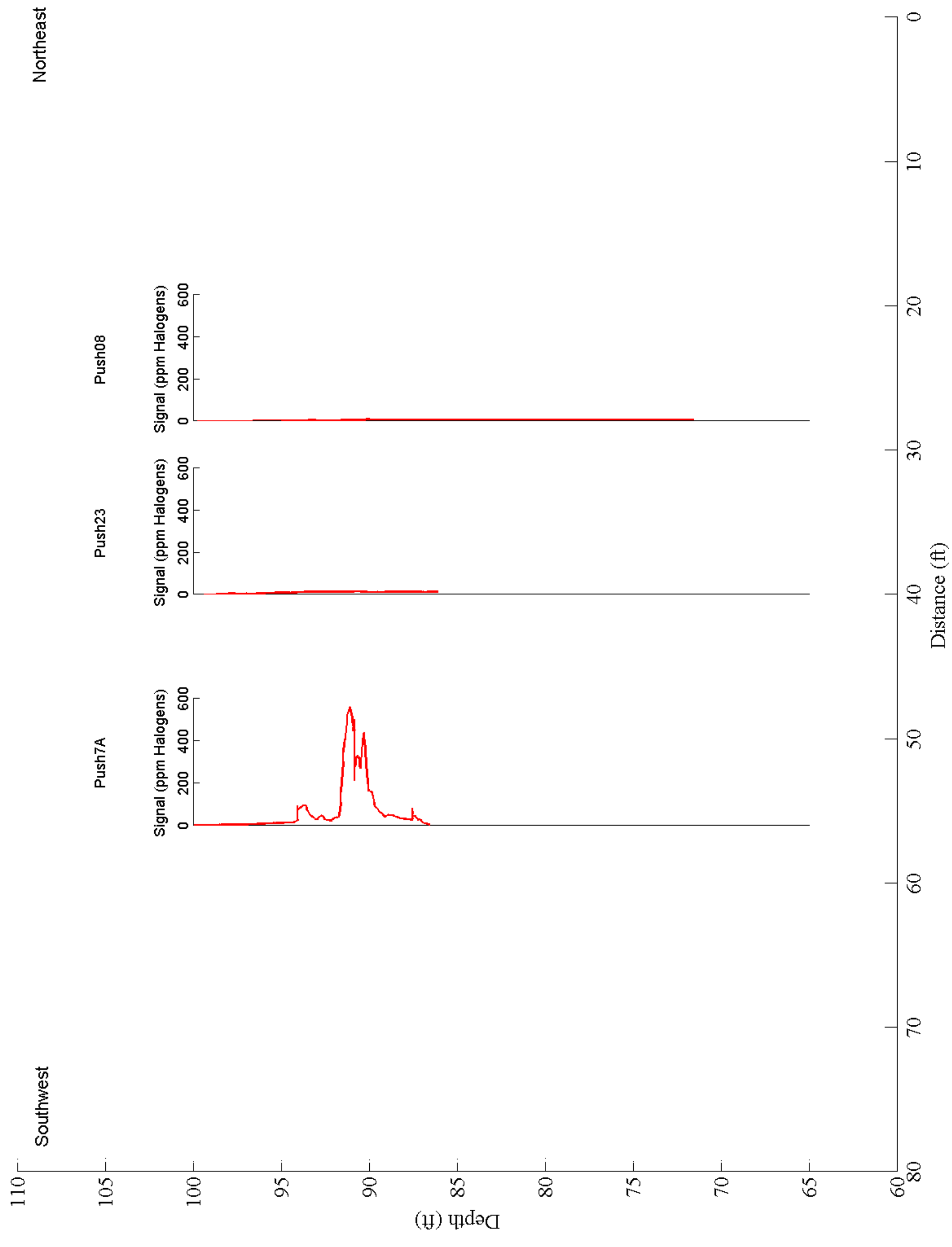
Push24
0
5
10
15
20
25
30
35
Depth (ft)
0
200
400
600
Signal (ppm Halogens)


Southwest
Northeast
Push24
Push01
Push02
Push03
Signal (ppm Halogens)
0 200 400 600
Depth (ft)
110 105 100 95 90 85 80 75 70 65 60
Distance (ft)
0 10 20 30 40 50 60 70 80

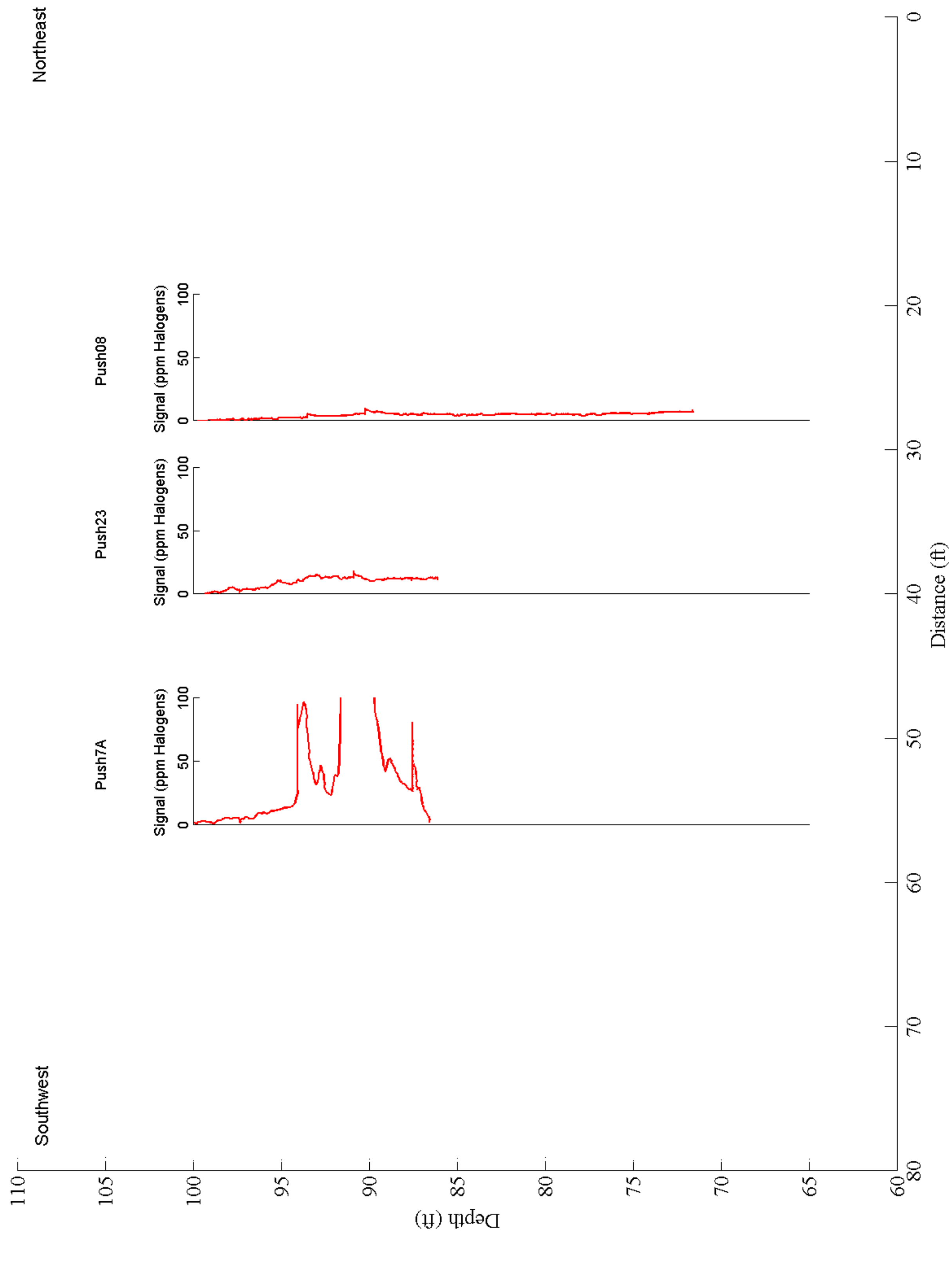

Southwest
Northeast
Push24
Push01
Push02
Push03
Signal (ppm Halogens)
0
50
100
Depth (ft)
110
105
100
95
90
85
80
75
70
65
60
Distance (ft)
0
10
20
30
40
50
60
70
80


Northeast
Southwest
Push04
Push05
Push06
Signal (ppm Halogens)
0
200
400
600
Depth (ft)
110
105
100
95
90
85
80
75
70
65
60
Distance (ft)
0
10
20
30
40
50
60
70
80

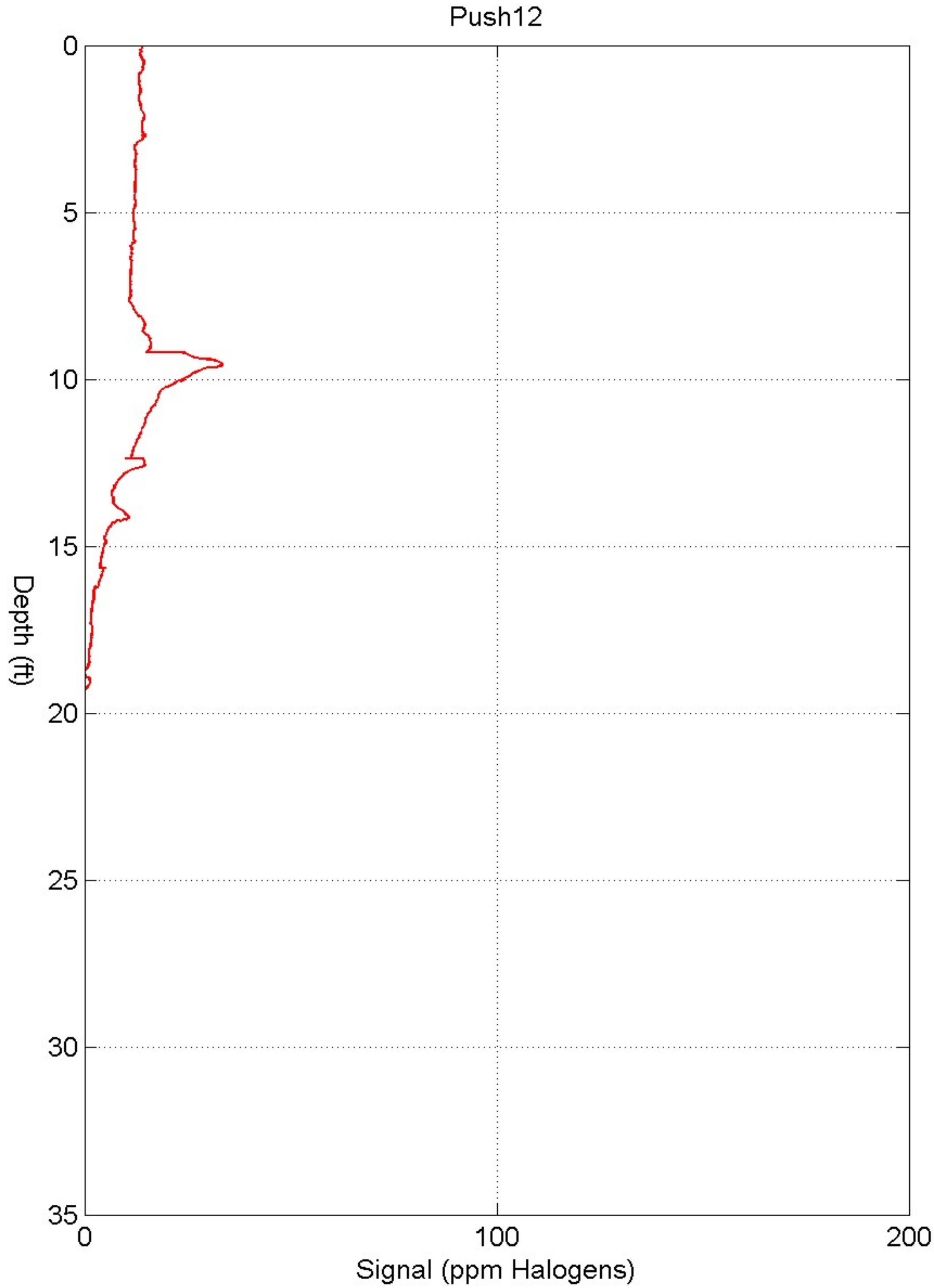

Southwest
Northeast
Push04
Push05
Push06
Signal (ppm Halogens)
Signal (ppm Halogens)
Signal (ppm Halogens)
Depth (ft)
Distance (ft)

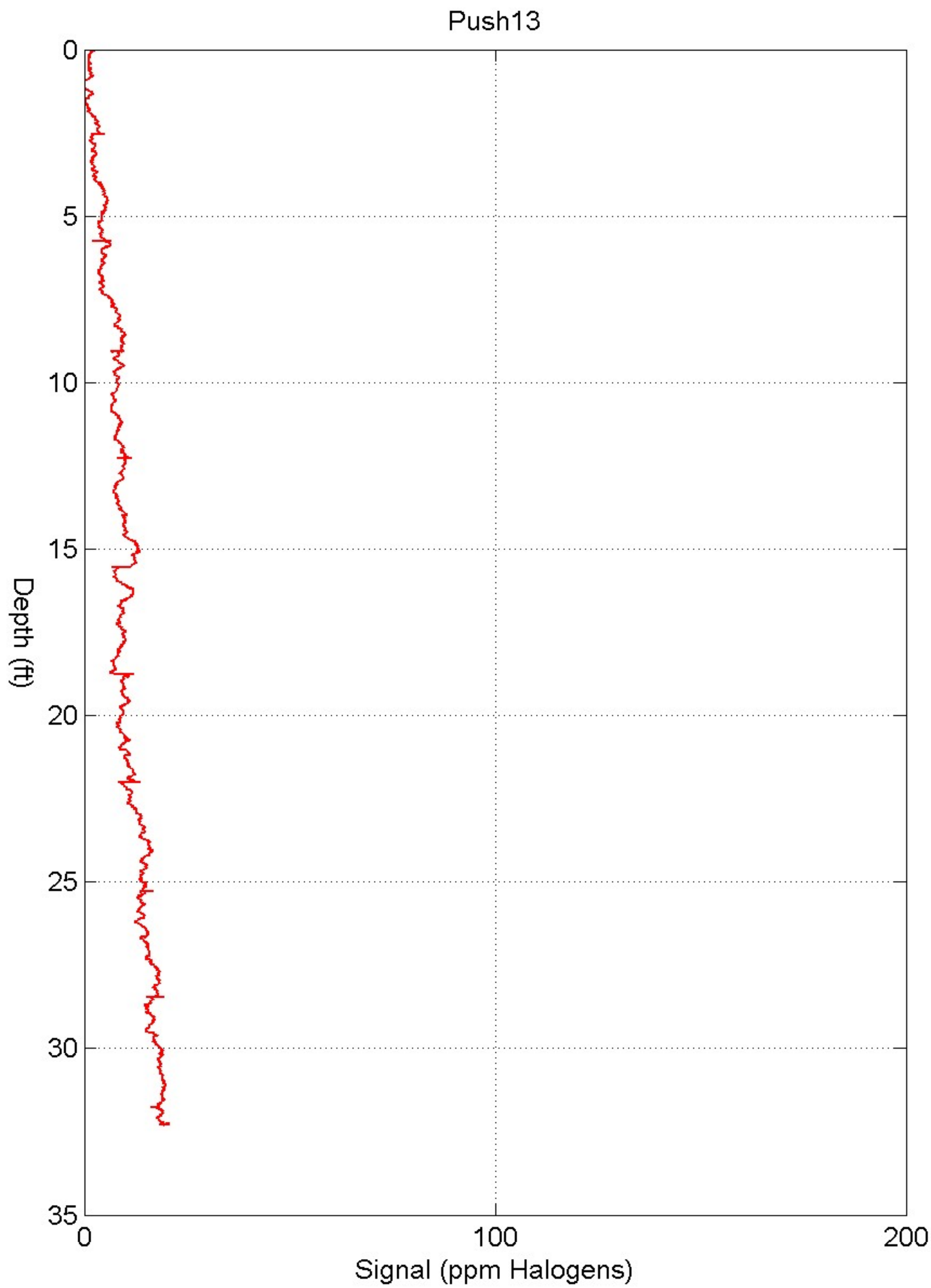


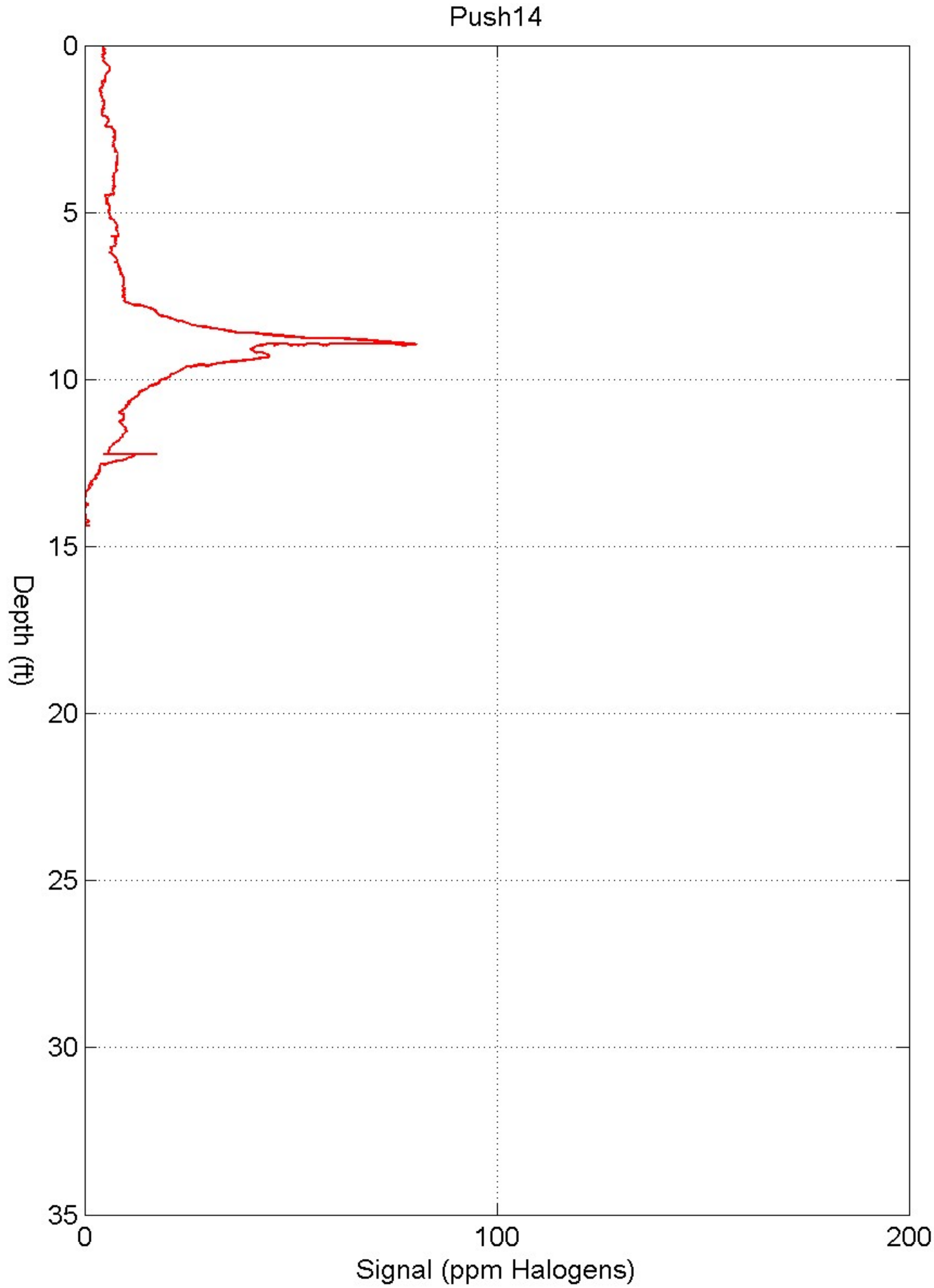
Northeast
Southwest
Push08
Push23
Push7A
Signal (ppm Halogens)
0
200
400
600
Depth (ft)
110
105
100
95
90
85
80
75
70
65
60
Distance (ft)
0
10
20
30
40
50
60
70
80



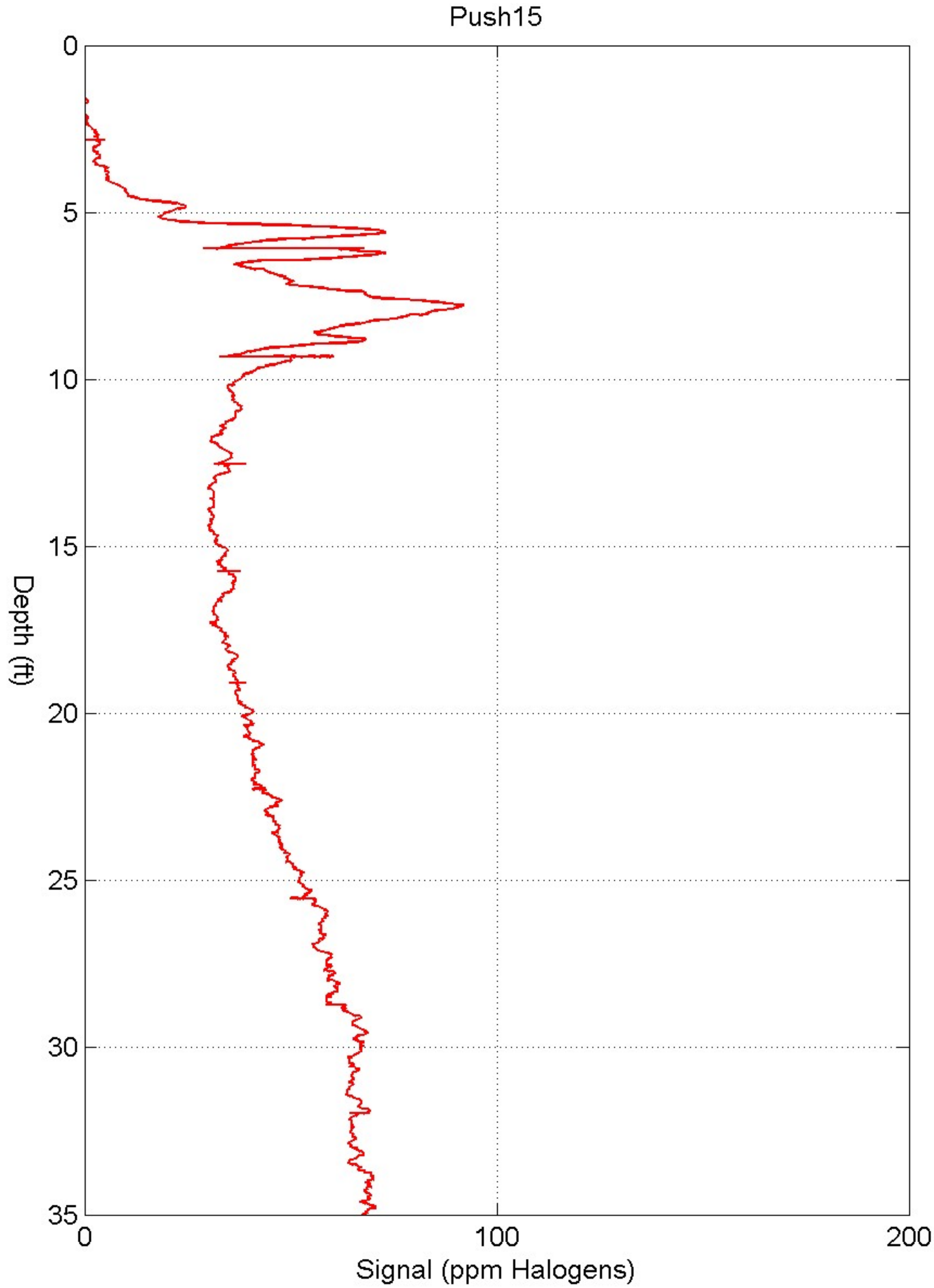
Northeast
Southwest
Push7A
Push23
Push08
Signal (ppm Halogens)
Signal (ppm Halogens)
Signal (ppm Halogens)
0
50
100
Depth (ft)
110
105
100
95
90
85
80
75
70
65
60
Distance (ft)
80
70
60
50
40
30
20
10
0

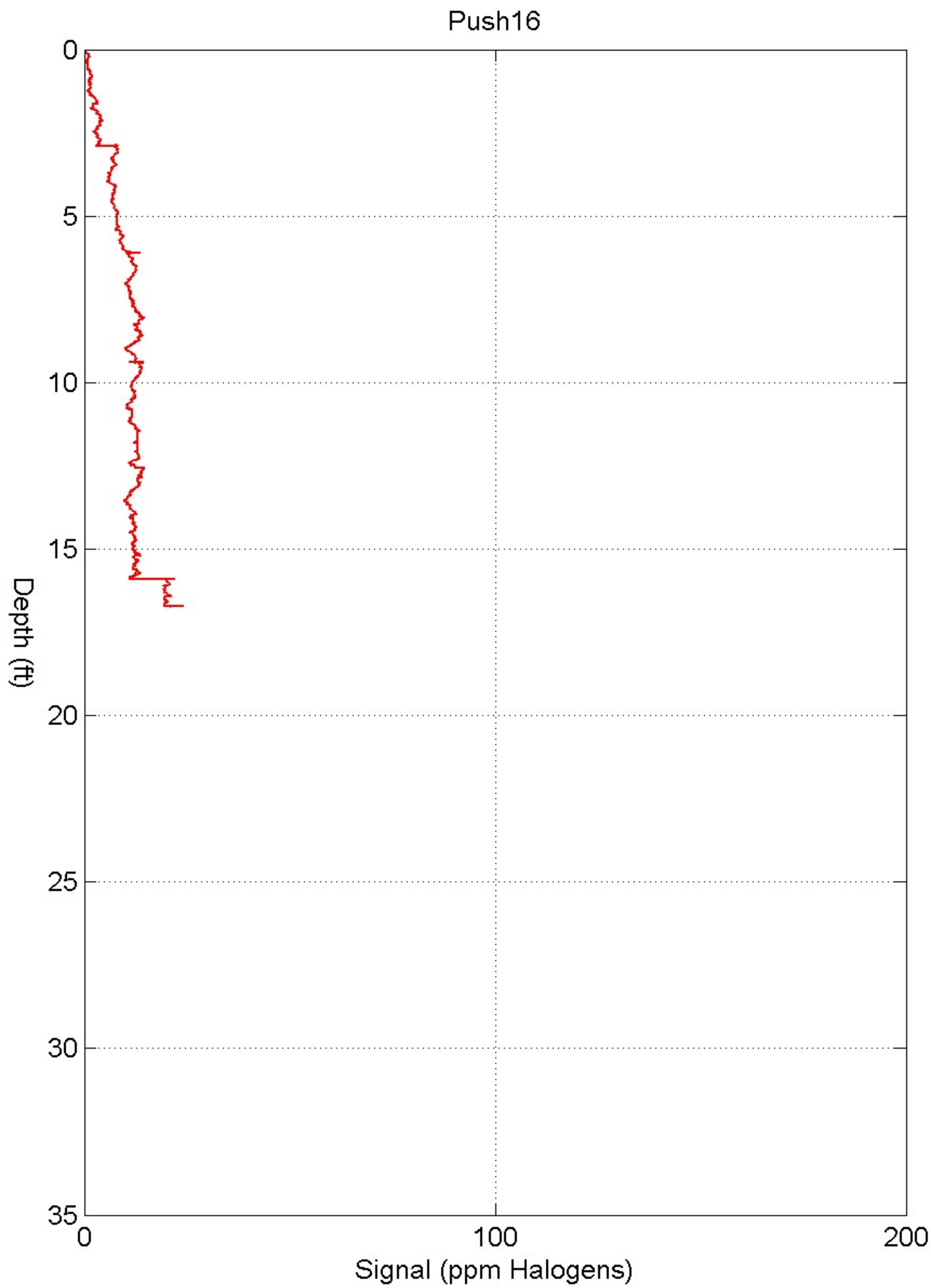

Push12
0
5
10
15
20
25
30
35
Depth (ft)
0
100
200
Signal (ppm Halogens)

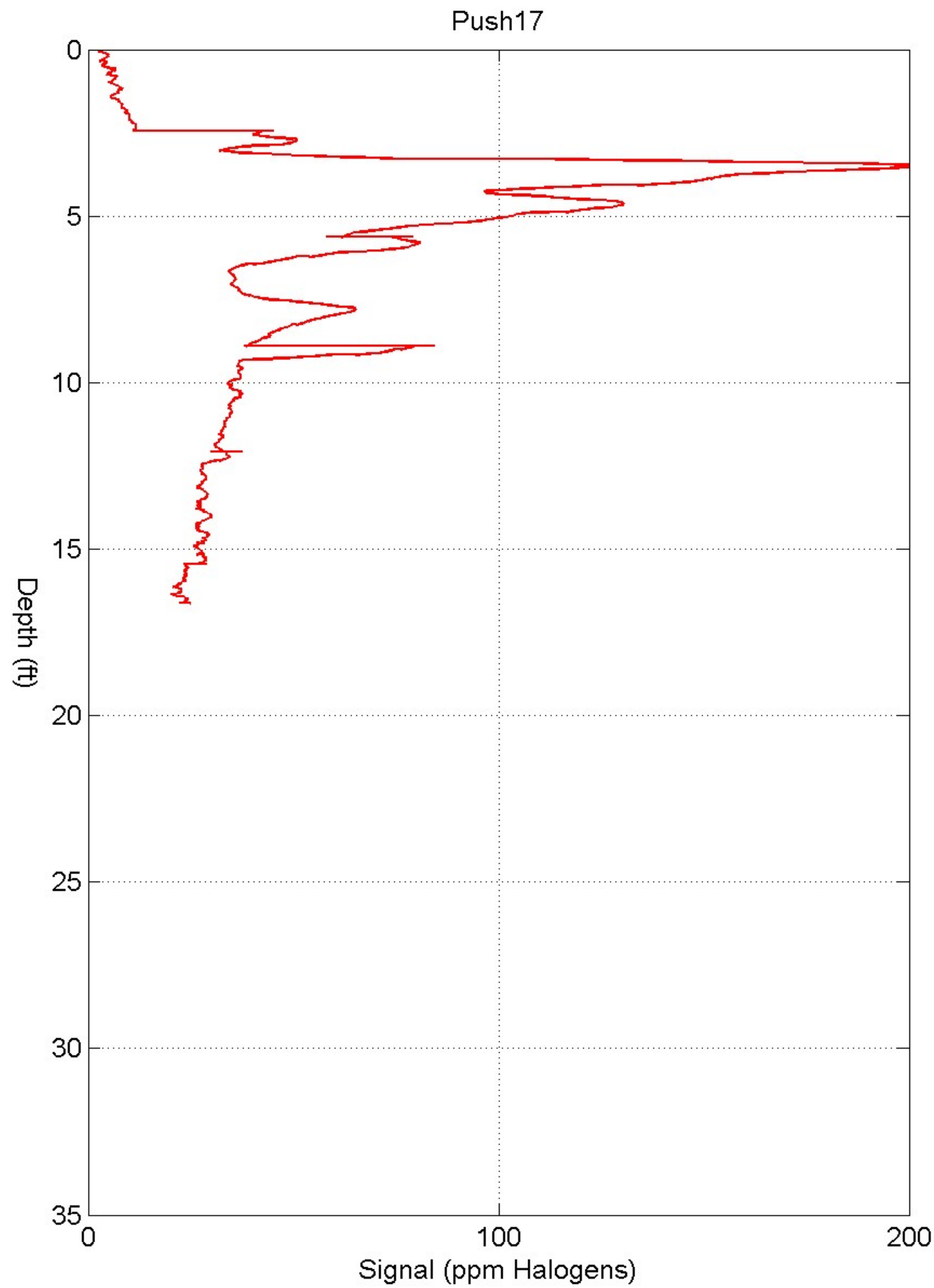

Push13
0
5
10
15
20
25
30
35
Depth (ft)
0
100
200
Signal (ppm Halogens)

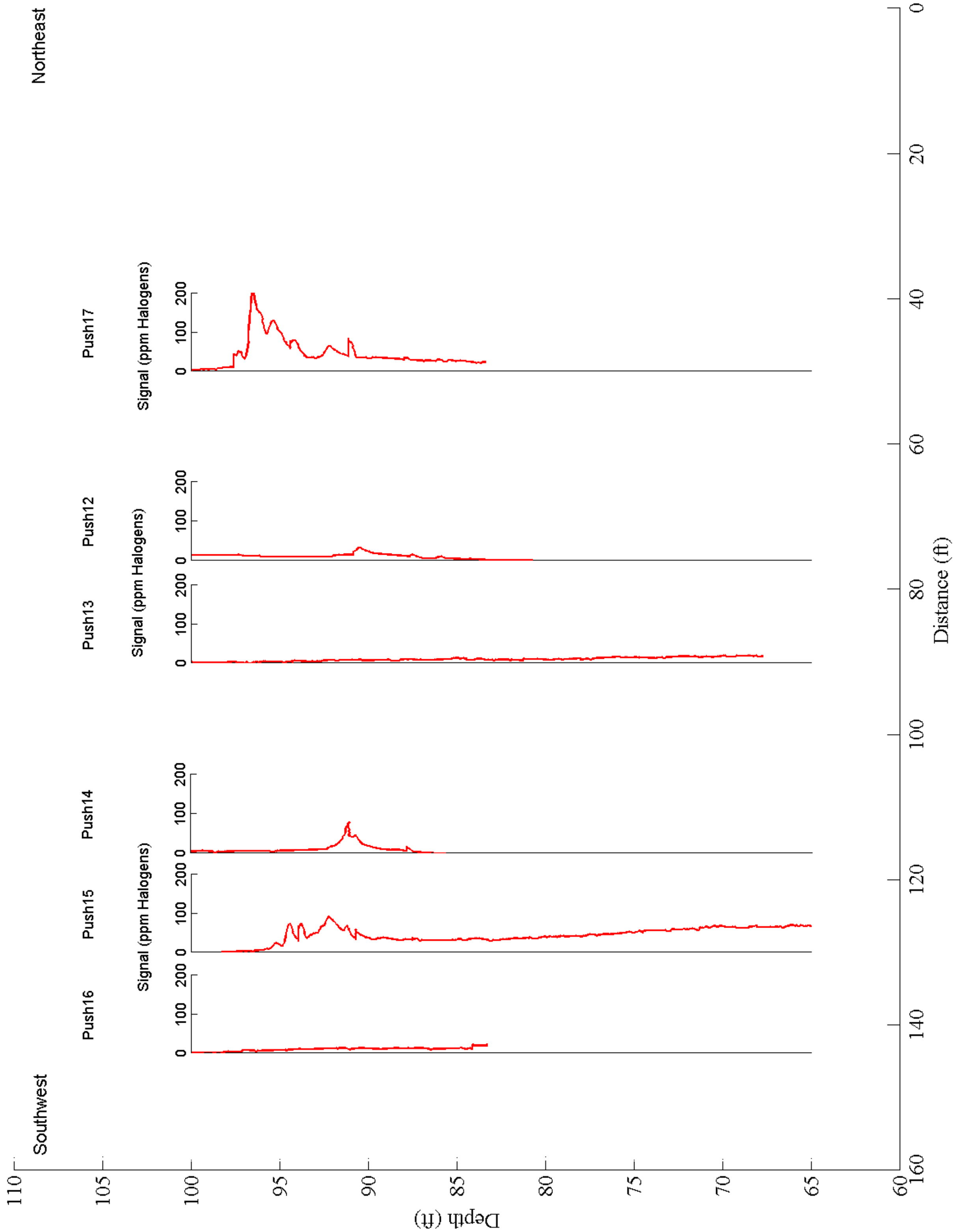


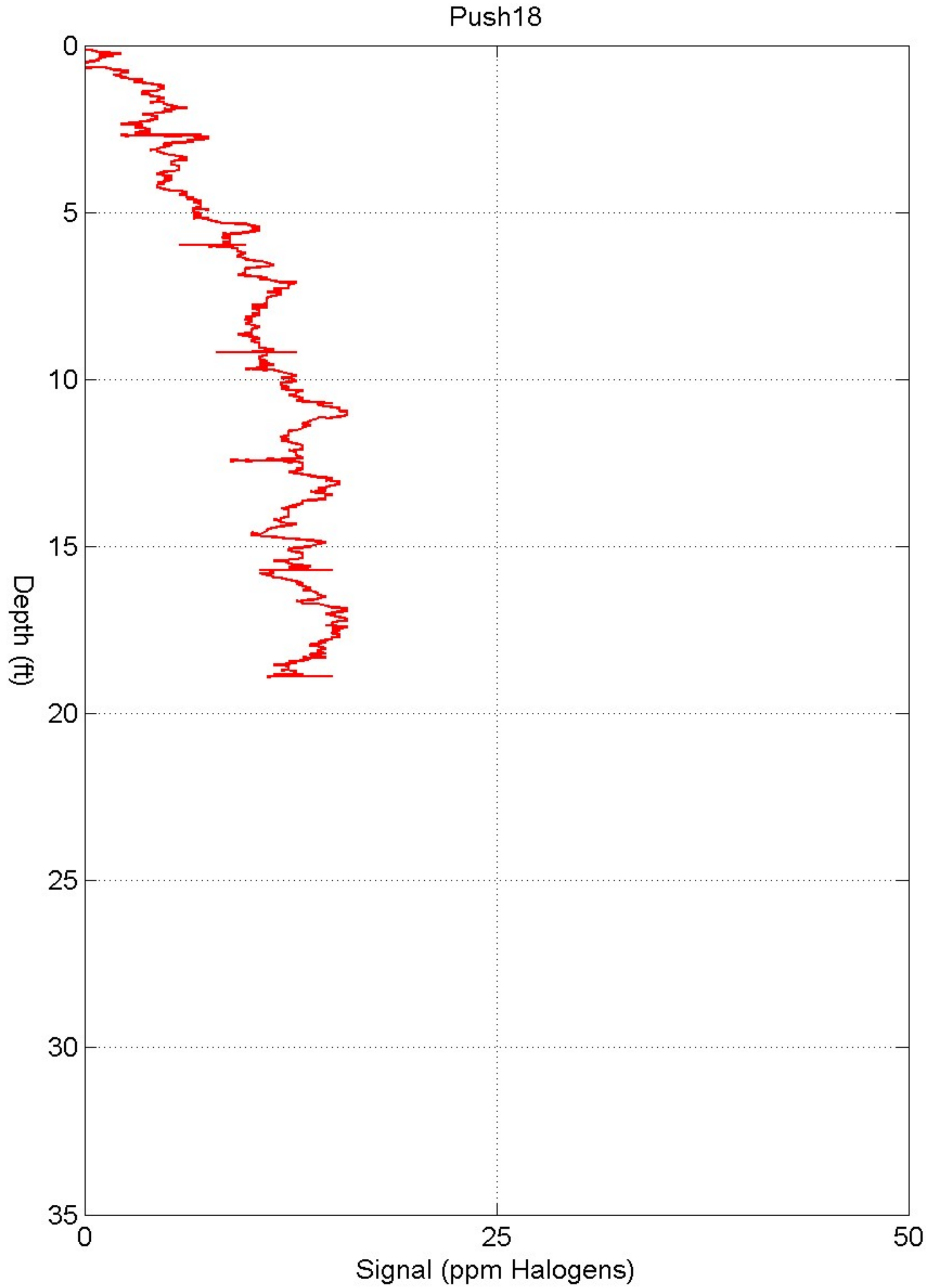
Push14
0
5
10
15
20
25
30
35
Depth (ft)
0
100
200
Signal (ppm Halogens)

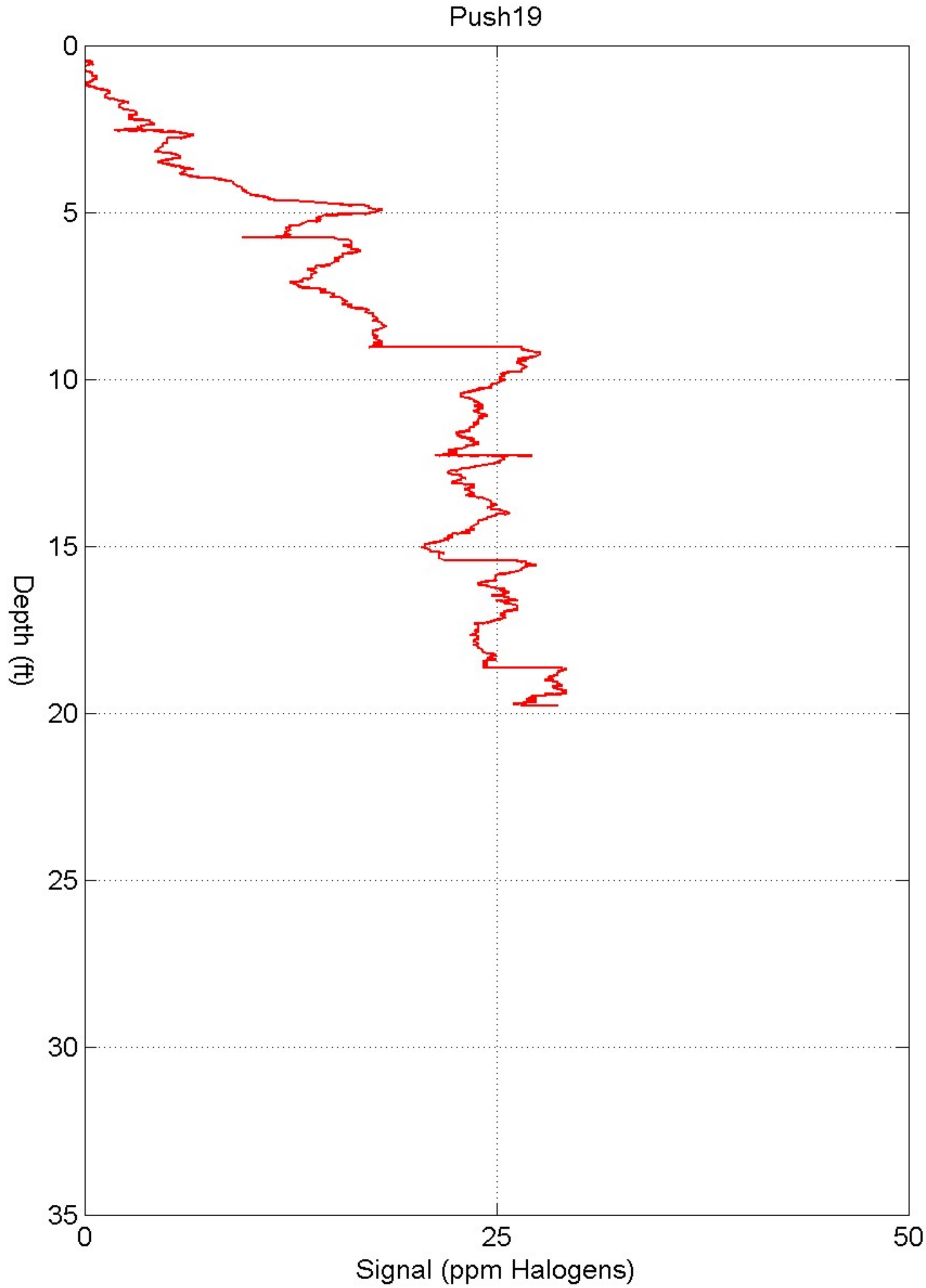

Push15
0
5
10
15
20
25
30
35
Depth (ft)
0
100
200
Signal (ppm Halogens)

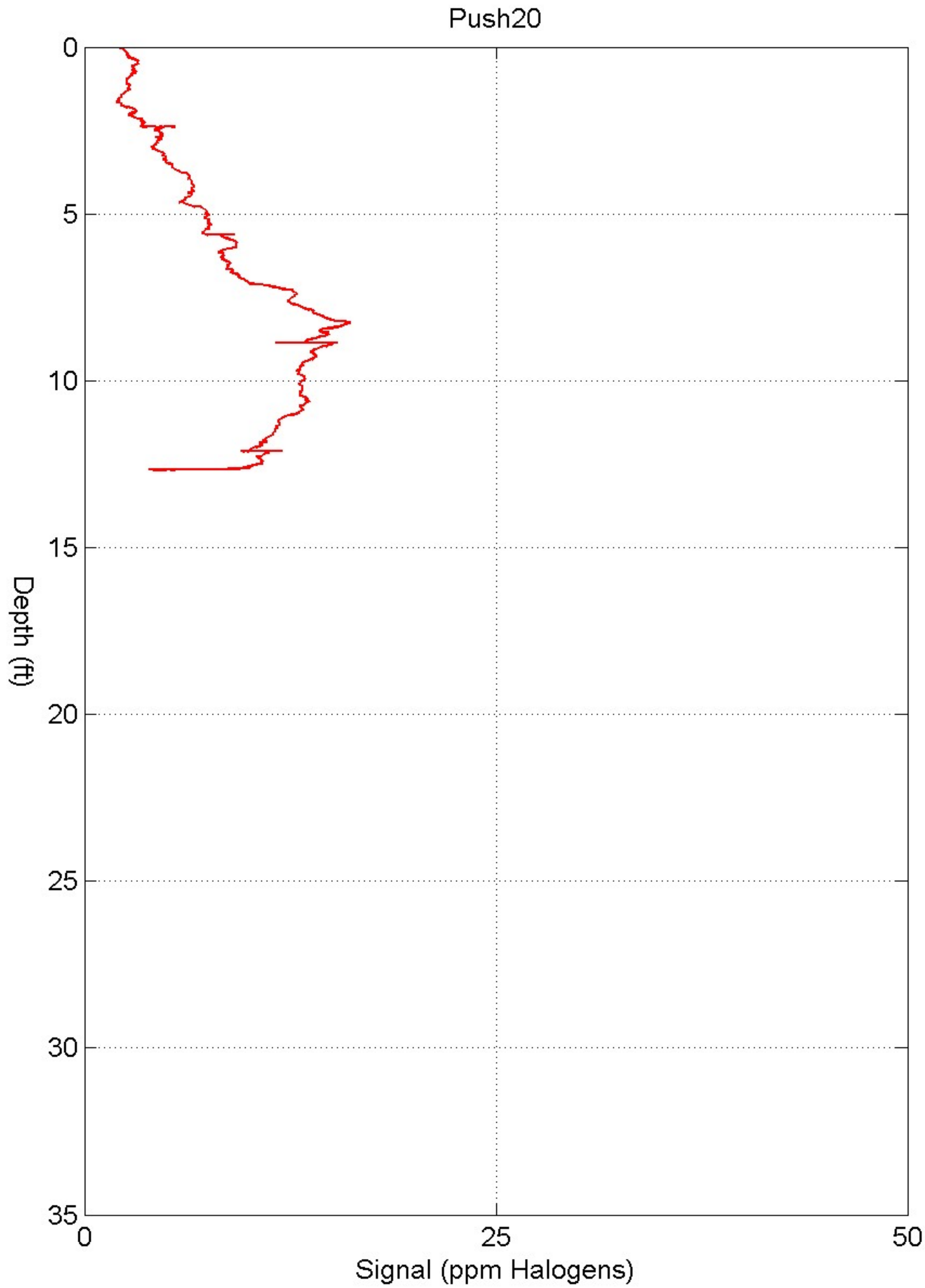

Push16
Depth (ft)
0
5
10
15
20
25
30
35
0
100
200
Signal (ppm Halogens)

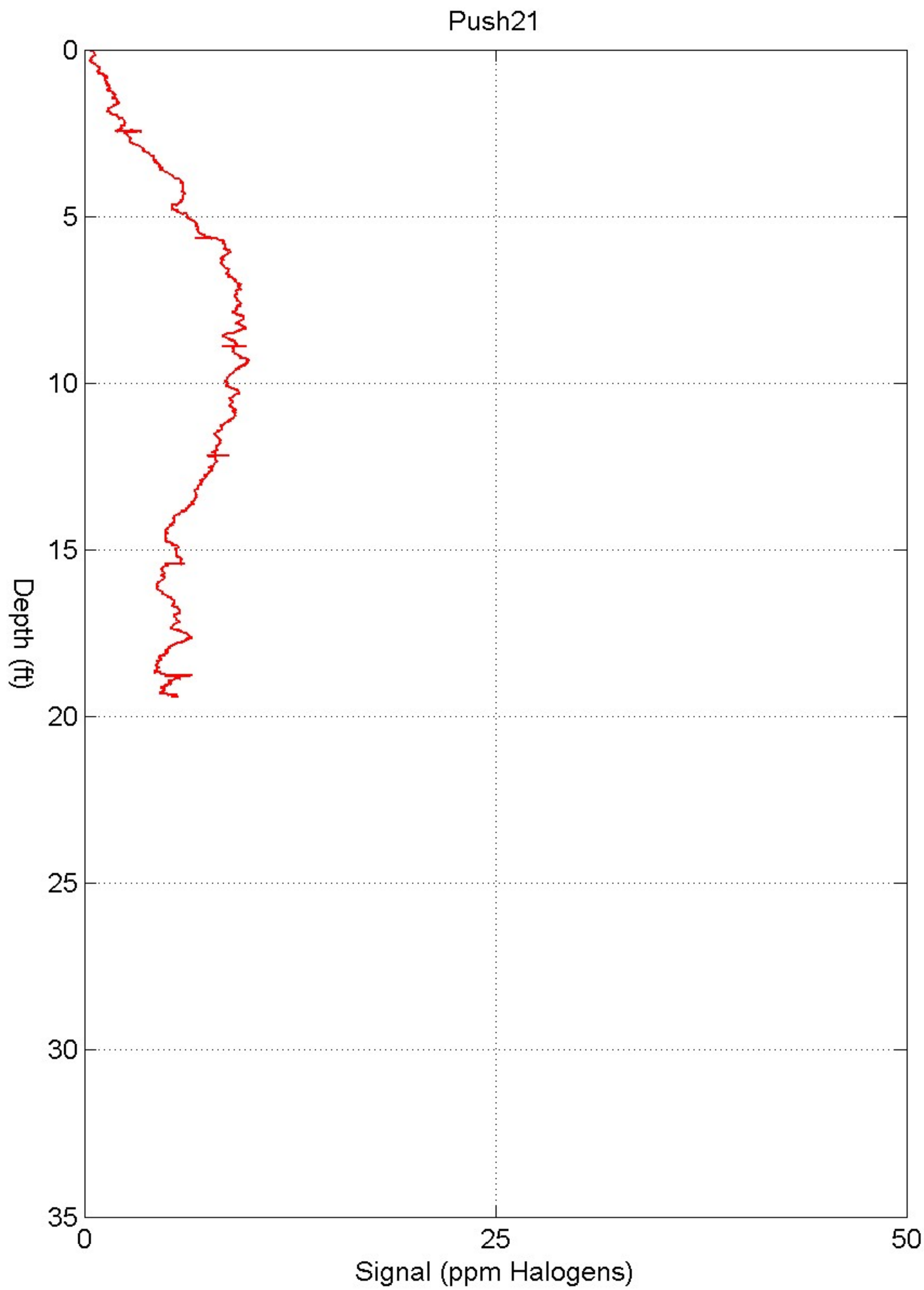

Push17
0
5
10
15
20
25
30
35
Depth (ft)
0
100
200
Signal (ppm Halogens)


Southwest
Northeast
Push16
Push15
Push14
Push13
Push12
Push17
Signal (ppm Halogens)
Depth (ft)
Distance (ft)
110
105
100
95
90
85
80
75
70
65
60
160
140
120
100
80
60
40
20
0
0
100
200

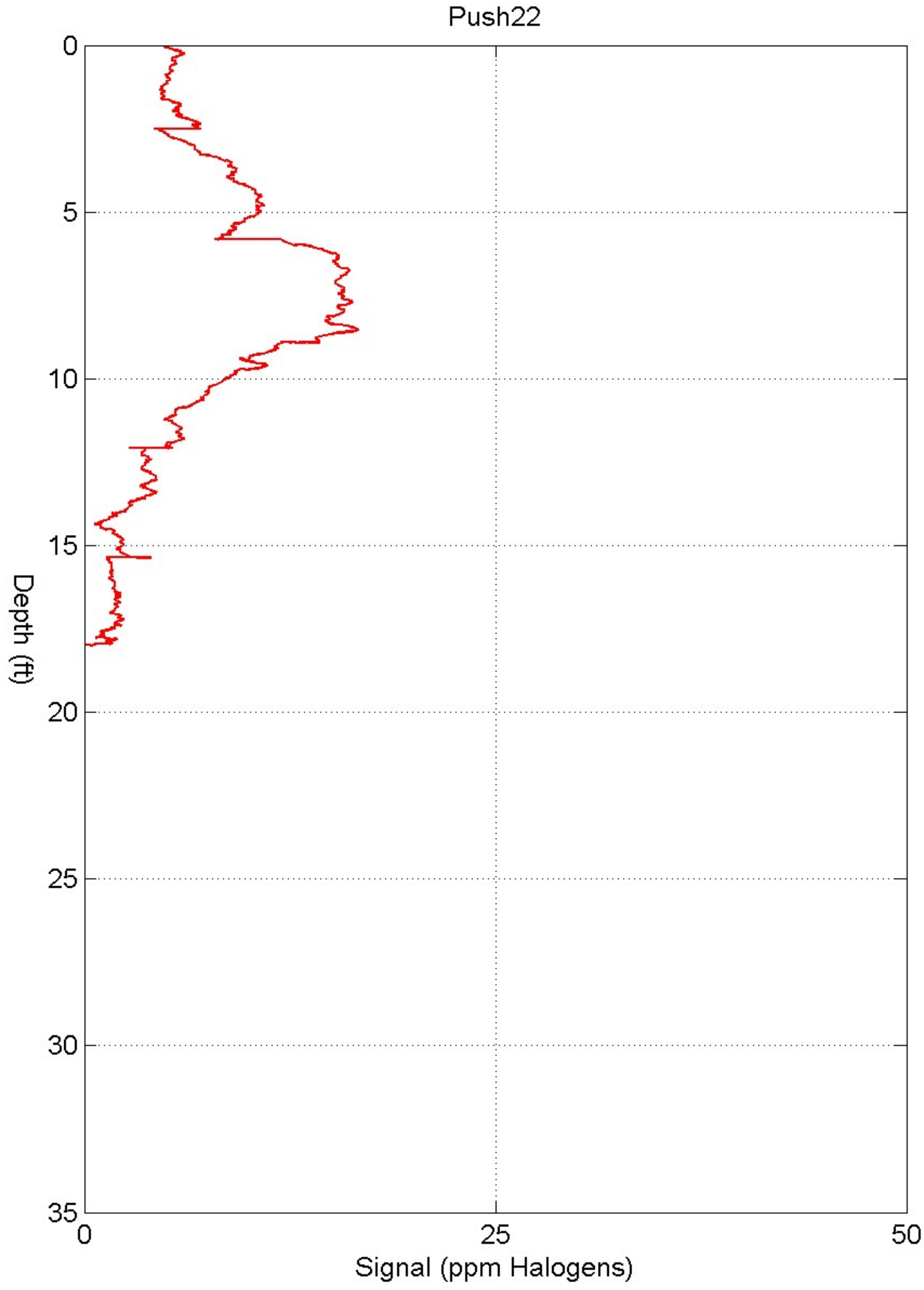

Push18
0
5
10
15
20
25
30
35
Depth (ft)
0
25
50
Signal (ppm Halogens)

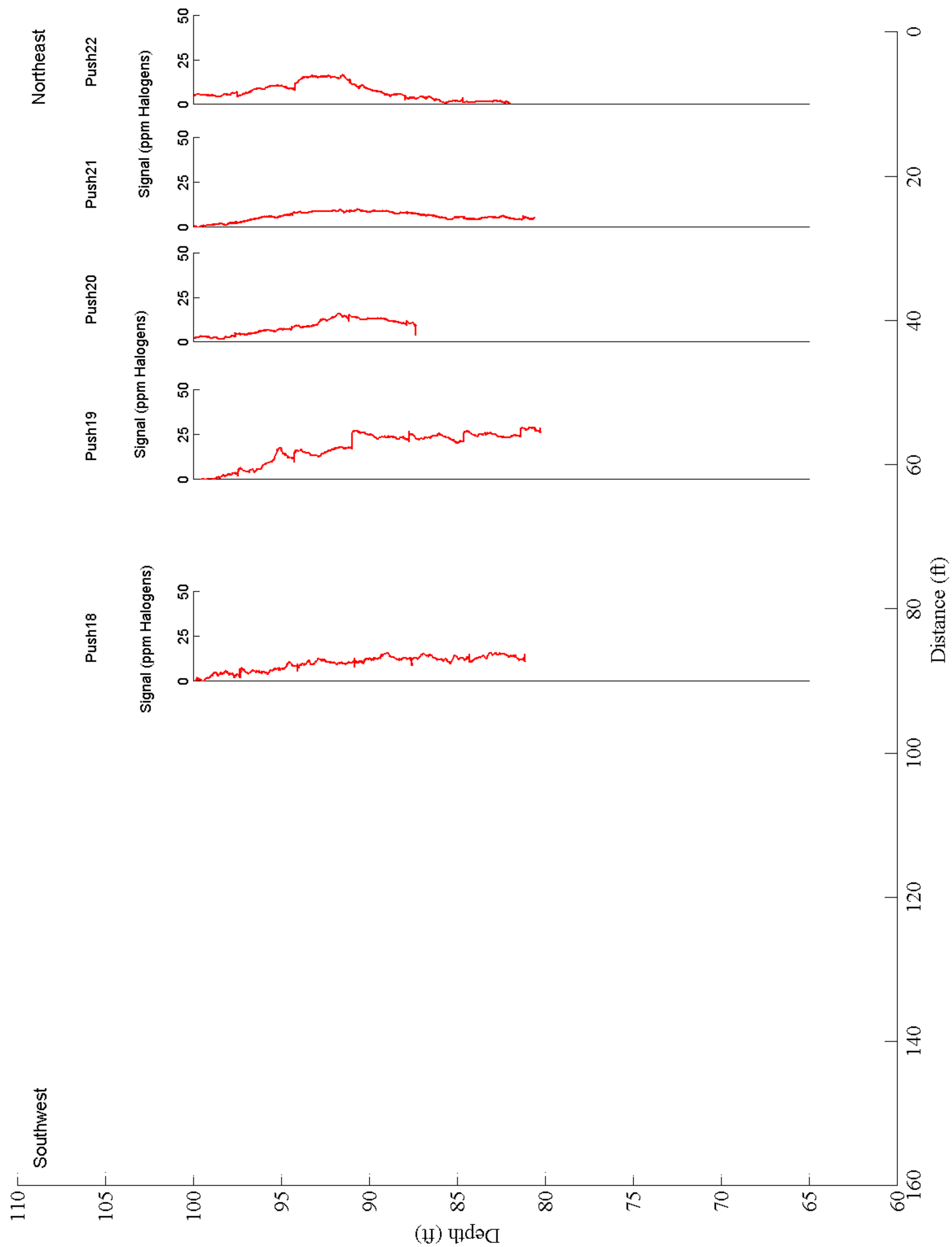

Push19
Depth (ft)
Signal (ppm Halogens)
0
5
10
15
20
25
30
35
0
25
50

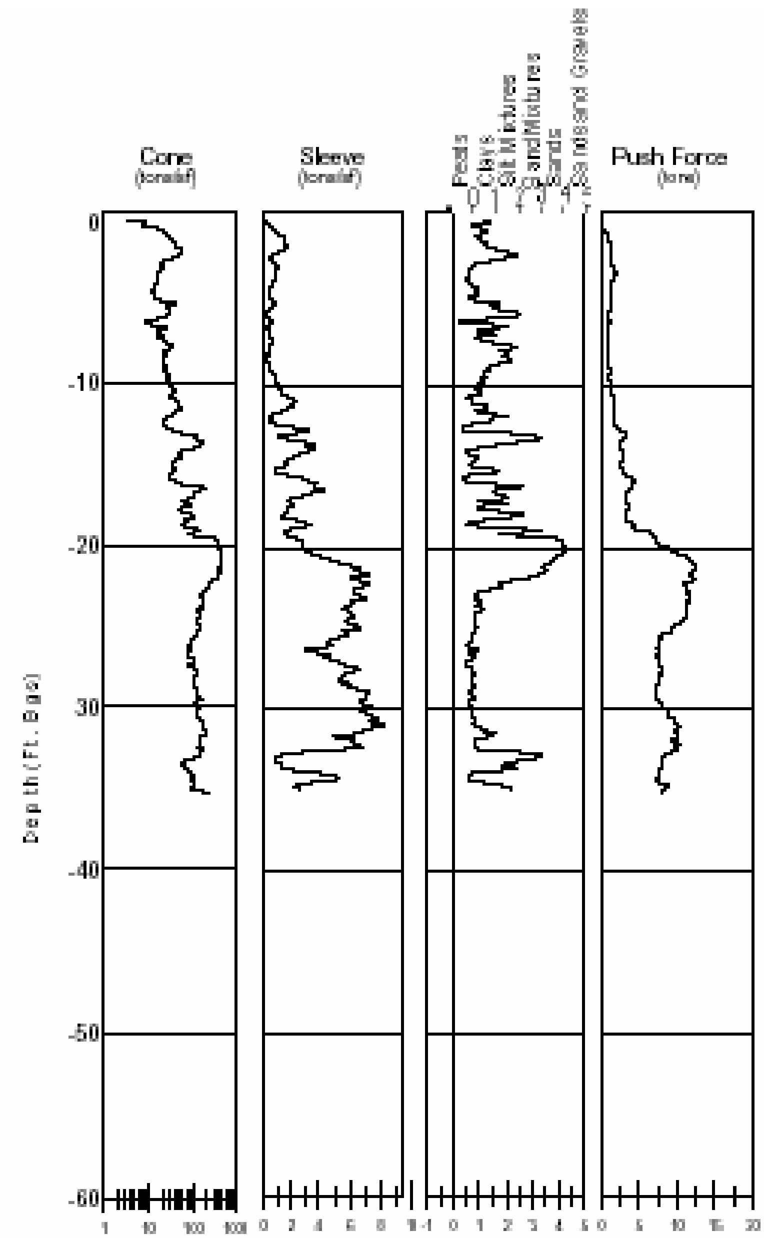

Push20
0
5
10
15
20
25
30
35
Depth (ft)
0
25
50
Signal (ppm Halogens)



Push21
0
5
10
15
20
25
30
35
Depth (ft)
0
25
50
Signal (ppm Halogens)


Push22
0
5
10
15
20
25
30
35
Depth (ft)
0
25
50
Signal (ppm Halogens)


Northeast
Southwest
Push22
Push21
Push20
Push19
Push18
Signal (ppm Halogens)
Depth (ft)
Distance (ft)



NWK
SCAPS

Push Date 12/12/20

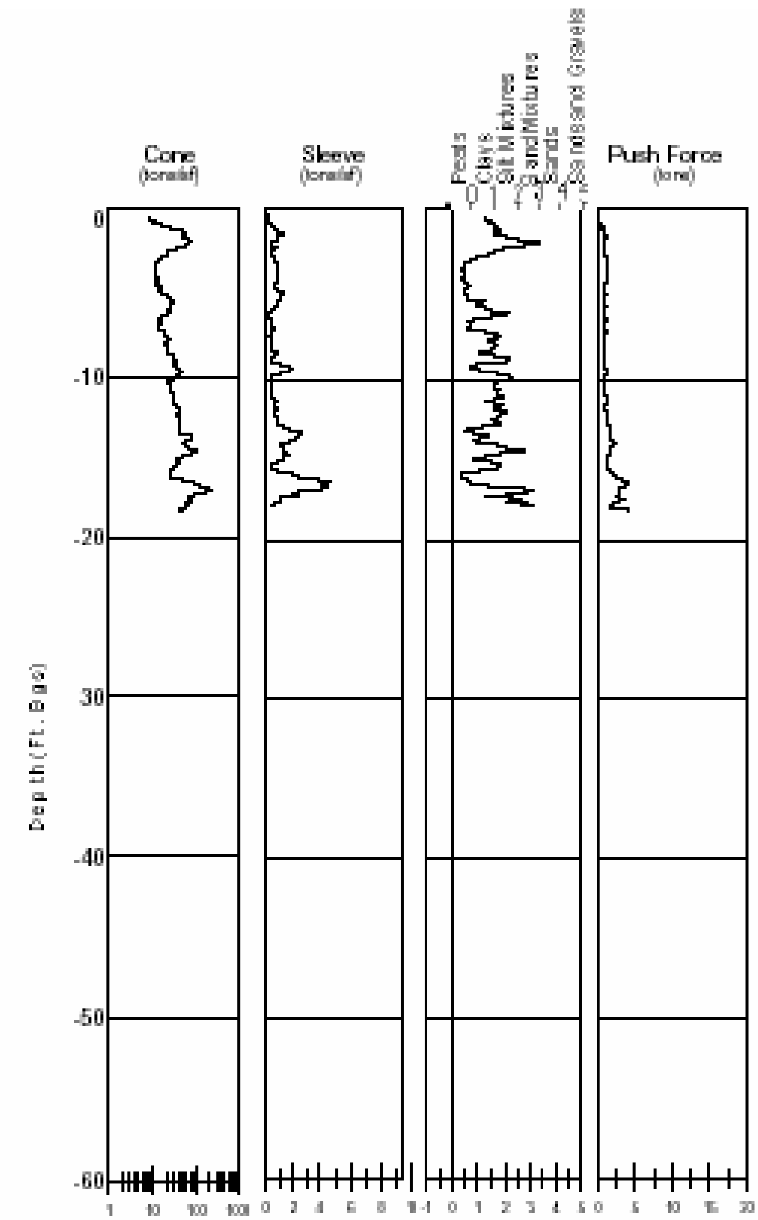
Project: Rickenbacker Site 41

Prepush Depth (Ft) 0.00

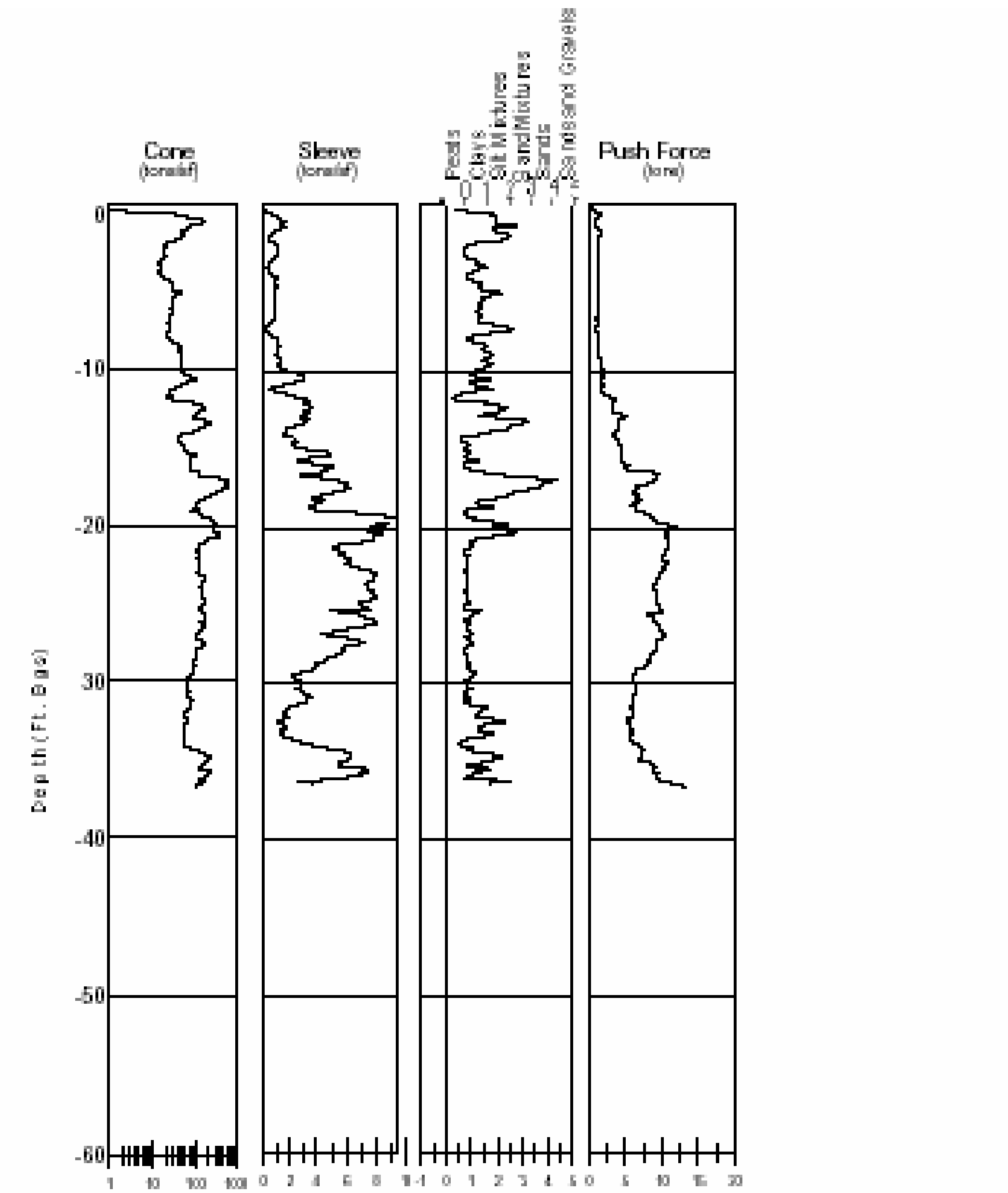
Probe Depth (Ft) 35.37

Scale 1"=10'

Push Name SCAPS2.QRF



NWK *SCAPS*	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/12/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 18.73 Scale 1"=10'	Project: Rickenbacker Site 41 Push Name SCAPS3.QRF



NWK SCAPS

Site Characterization and Analysis Penetrometer System

U.S. Army Engineer District Kansas City Geotechnical Branch

Push Date 12/12/20

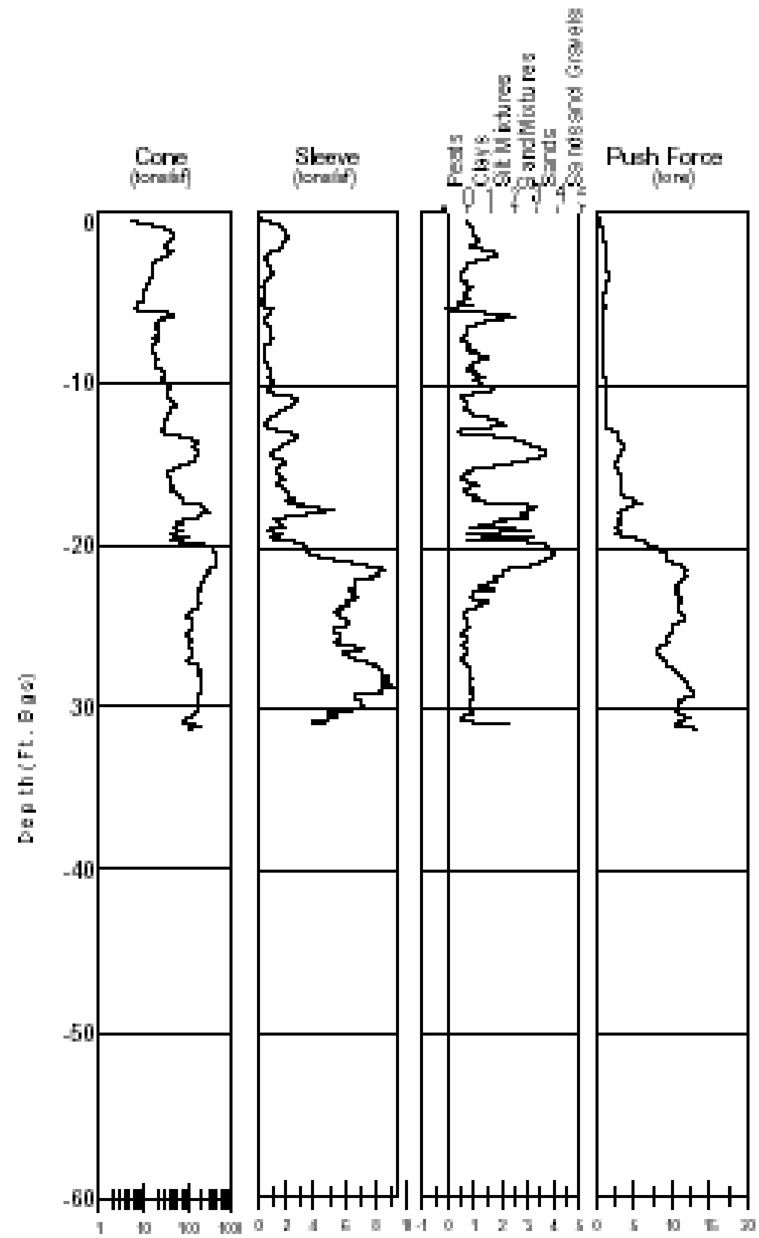
Prepush Depth (Ft) 0.00

Probe Depth (Ft) 36.90

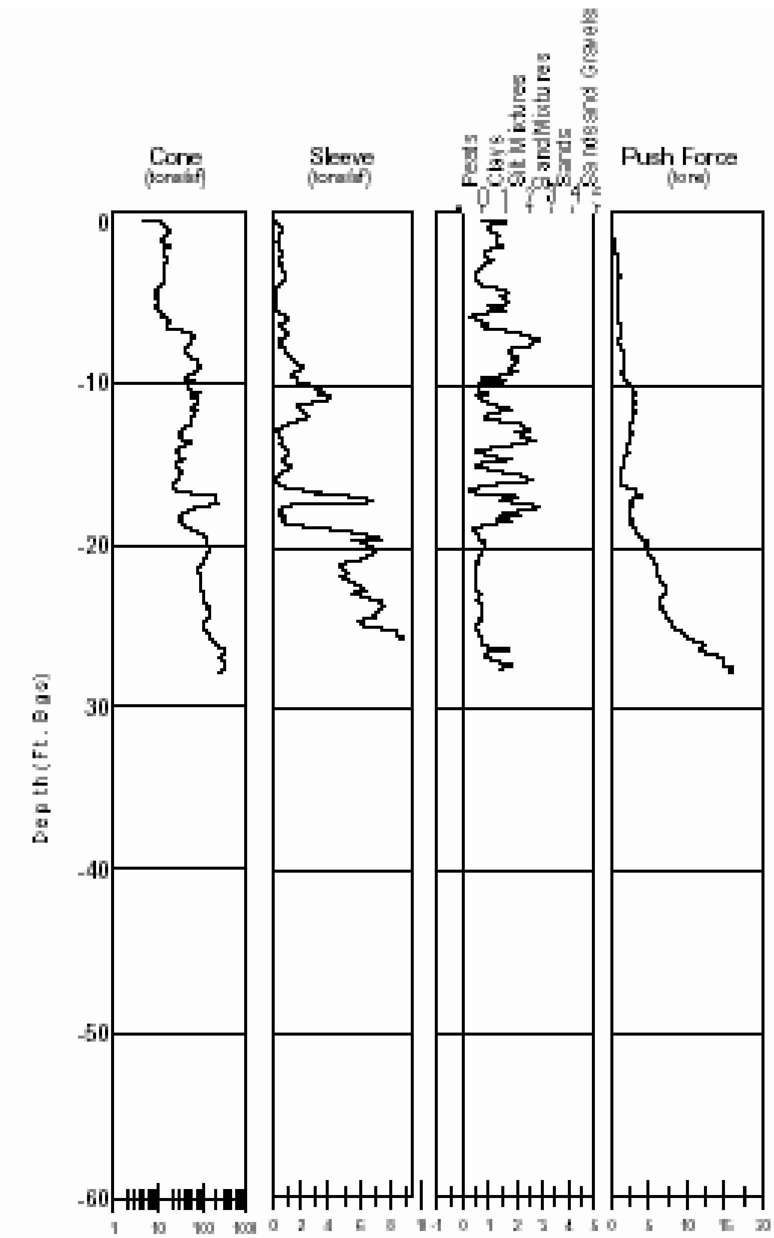
Scale 1"=10'

Project: Rickenbacker Site 41

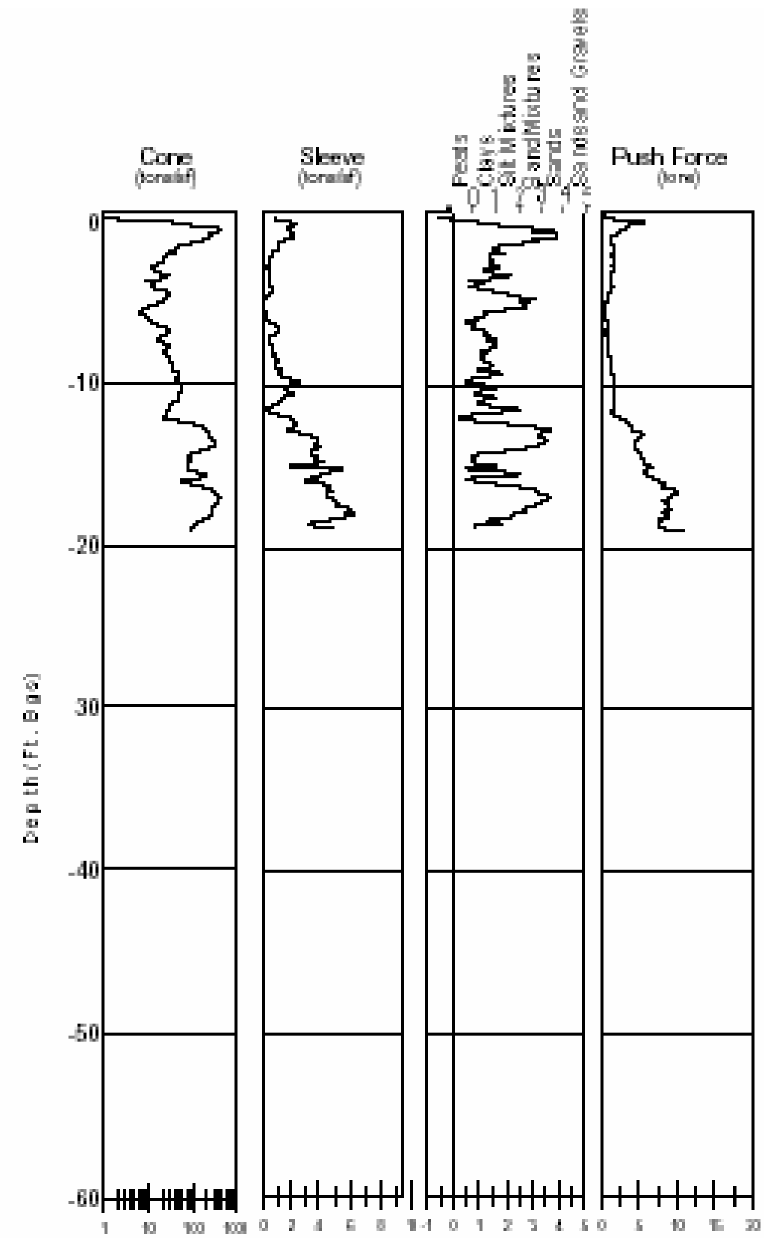
Push Name SCAPS4.QRF



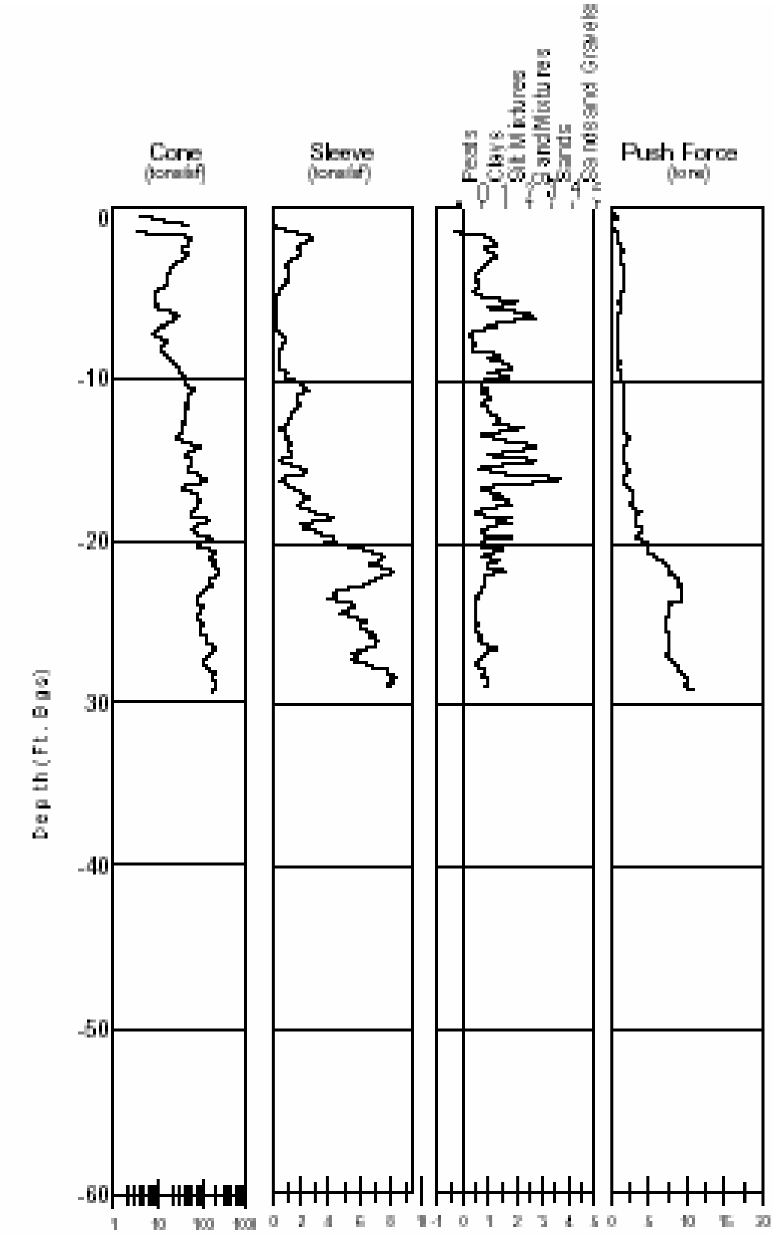
NWK SCAPS	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/12/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 31.53 Scale 1"=10'	Project: Rickenbacker Site 41 Push Name SCAPS5.QNF



NWK SCAPS	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/12/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 28.10 Scale 1"=10'	Project: Rickenbacker Site 41 Push Name SCAPS6.QNF



NWK *SCAPS*	Push Date 12/12/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 19.47 Scale 1"=10'	Project: Rickenbacker Site 41 Push Name SCAPS7.QNF



NWK SCAPS

Site Characterization and Analysis Penetrometer System

U.S. Army Engineer District Kansas City Geotechnical Branch

Push Date 12/12/20

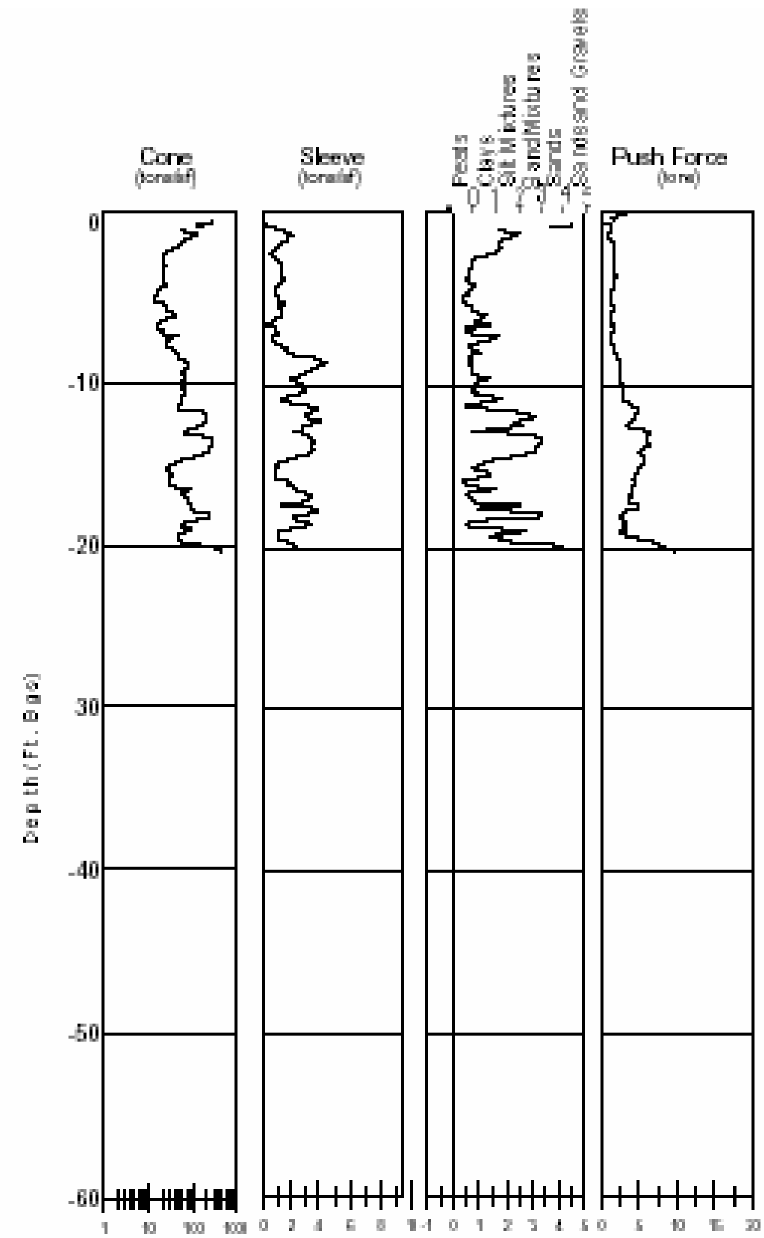
Prepush Depth (Ft) 0.00

Probe Depth (Ft) 29.52

Scale 1"=10'

Project: Rickenbacker Site 41

Push Name SCAPS8.QNF



NWK SCAPS

Site Characterization and Analysis Penetrometer System

US Army Engineer District Kansas City Geotechnical Branch

Push Date 12/12/20

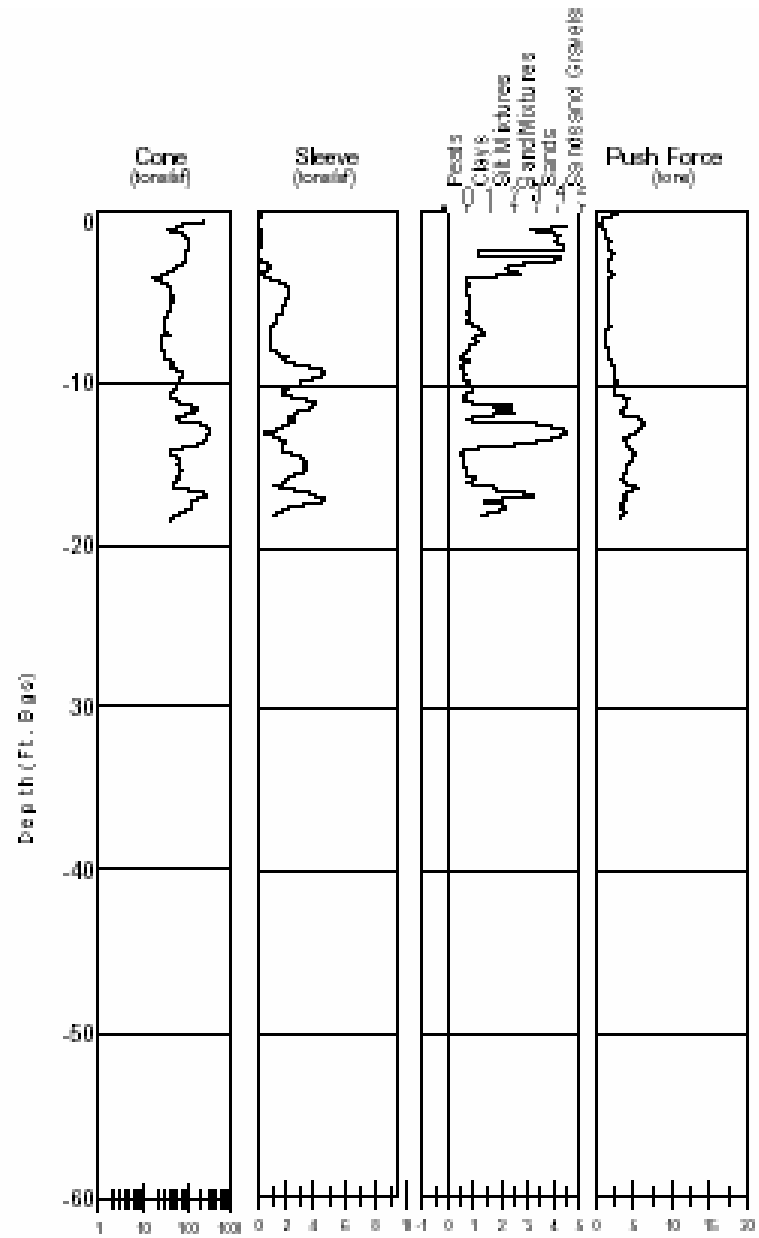
Prepush Depth (Ft) 0.00

Probe Depth (Ft) 20.75

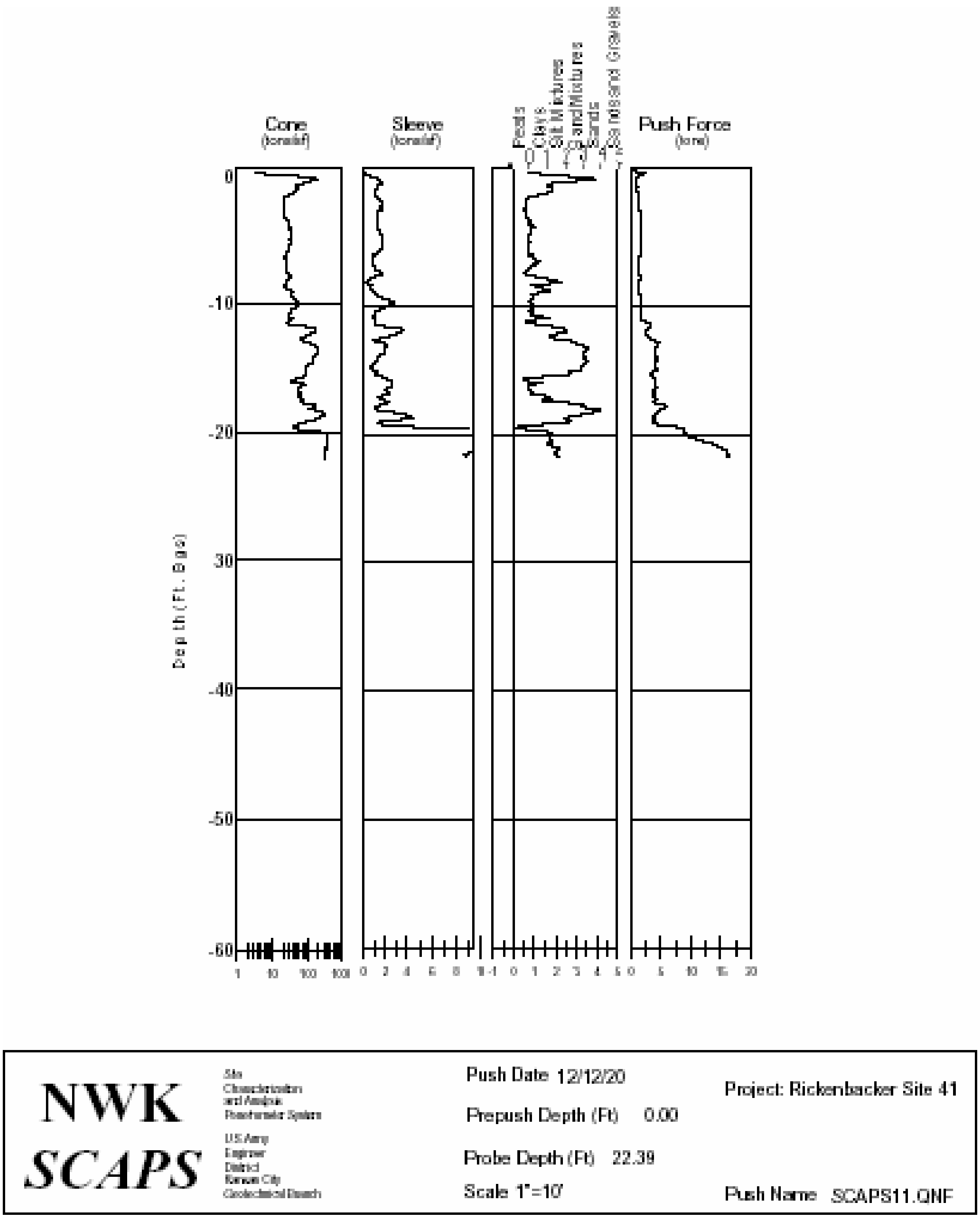
Scale 1"=10'

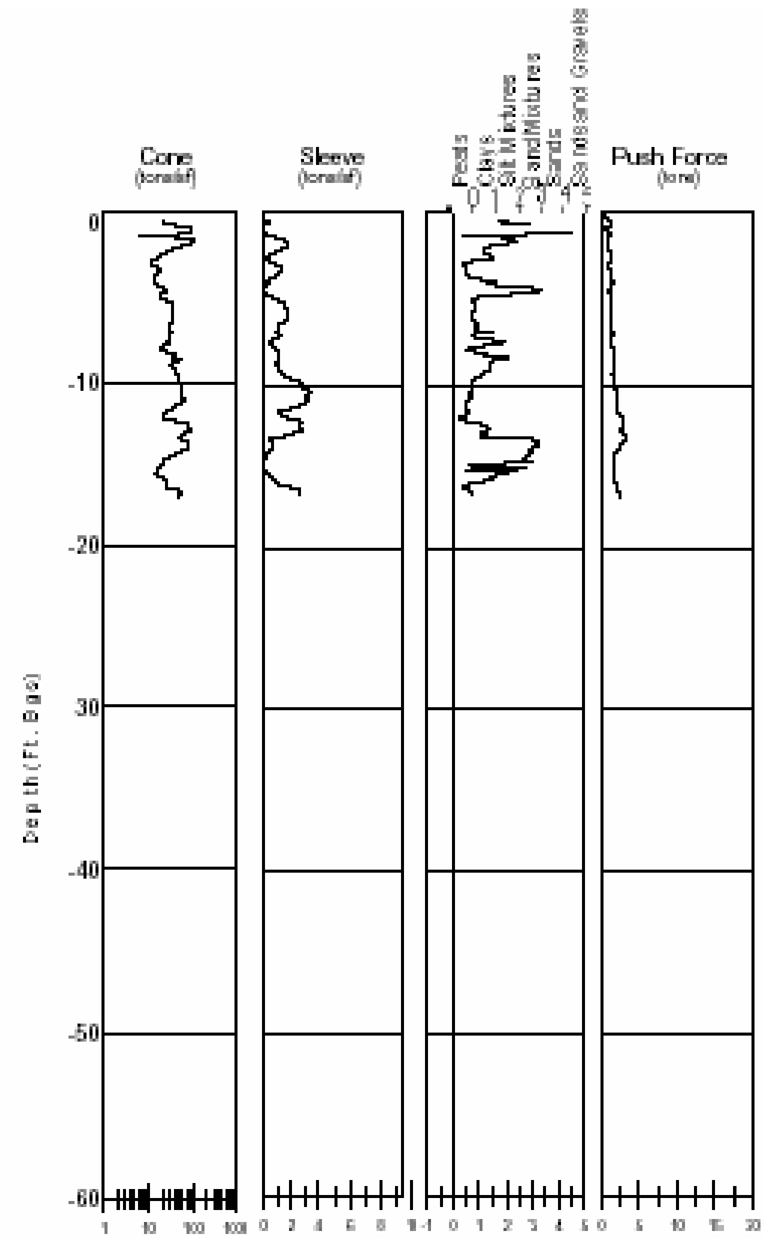
Project: Rickenbacker Site 41

Push Name SCAPS9.QNF

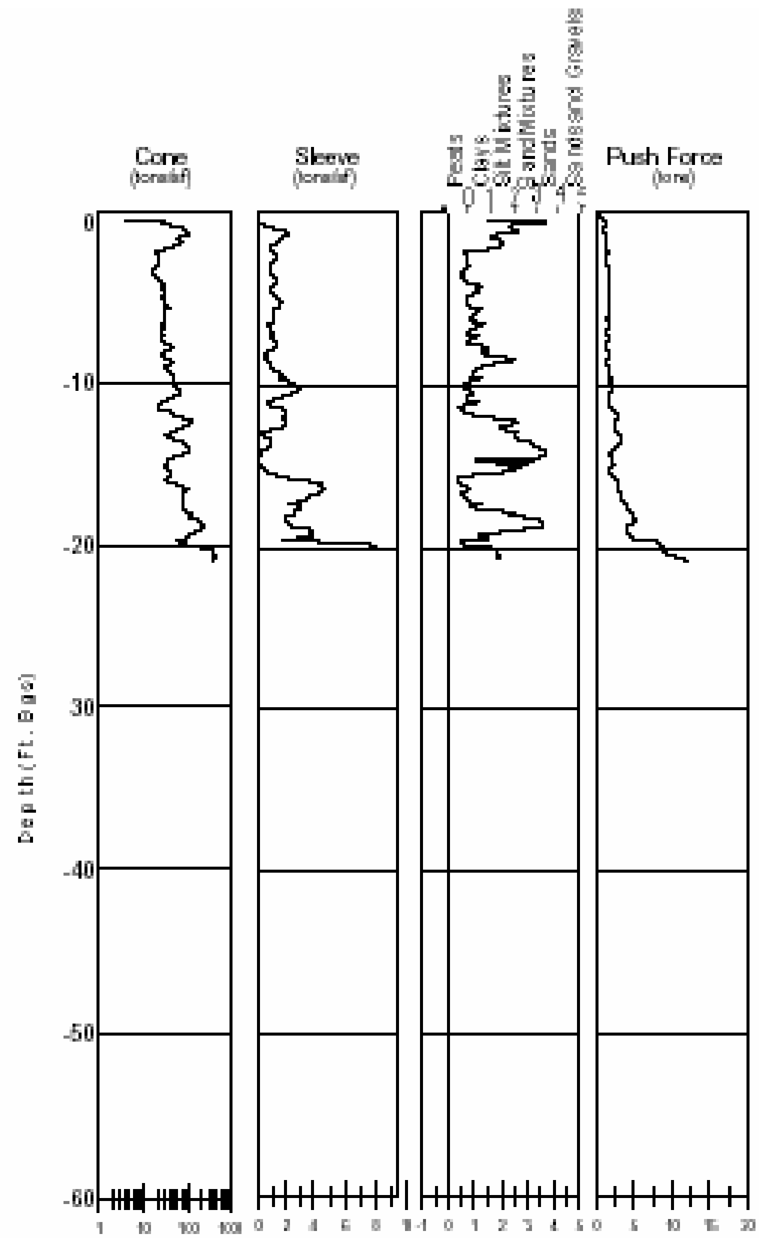


NWK SCAPS	Site Characterization and Analysis Penetrometer System; US Army Engineer District Kansas City Geotechnical Branch	Push Date 12/12/20	Project: Rickenbacker Site 41
		Prepush Depth (Ft) 0.00	
		Probe Depth (Ft) 18.79	
		Scale 1"=10'	Push Name SCAPS10.QNF


Cone
Sleeve
Peats
Clays
Silt Mixtures
Sand Mixtures
Sands
Sands and Gravels
Push Force
0
-10
-20
30
-40
-50
-60
NWK
SCAPS
Push Date 12/12/20
Prepush Depth (Ft) 0.00
Probe Depth (Ft) 22.39
Scale 1"=10'
Project: Rickenbacker Site 41
Push Name SCAPS11.QNF



NWK SCAPS	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/12/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 17.39 Scale 1"=10'	Project: Rickenbacker Site 41 Push Name SCAPS11A.QNF



NWK
SCAPS

Site Characterization and Analysis Penetrometer System

U.S. Army Engineer District Kansas City Geotechnical Branch

Push Date 12/12/20

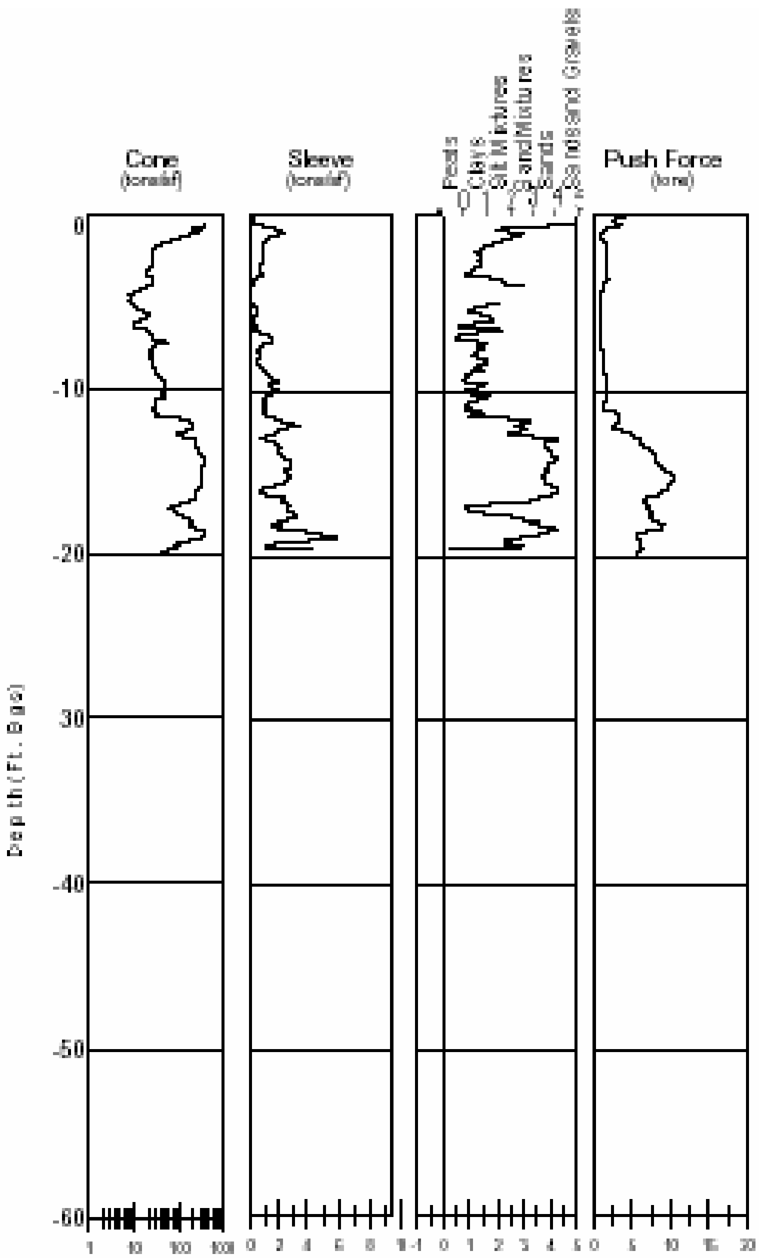
Prepush Depth (Ft) 0.00

Probe Depth (Ft) 21.29

Scale 1"=10'

Project: Rickenbacker Site 41

Push Name SCAPS11B.QNF



NWK SCAPS

Site Characterization and Analysis Penetrometer System

US Army Engineer District Kansas City Geotechnical Branch

Push Date 12/16/20

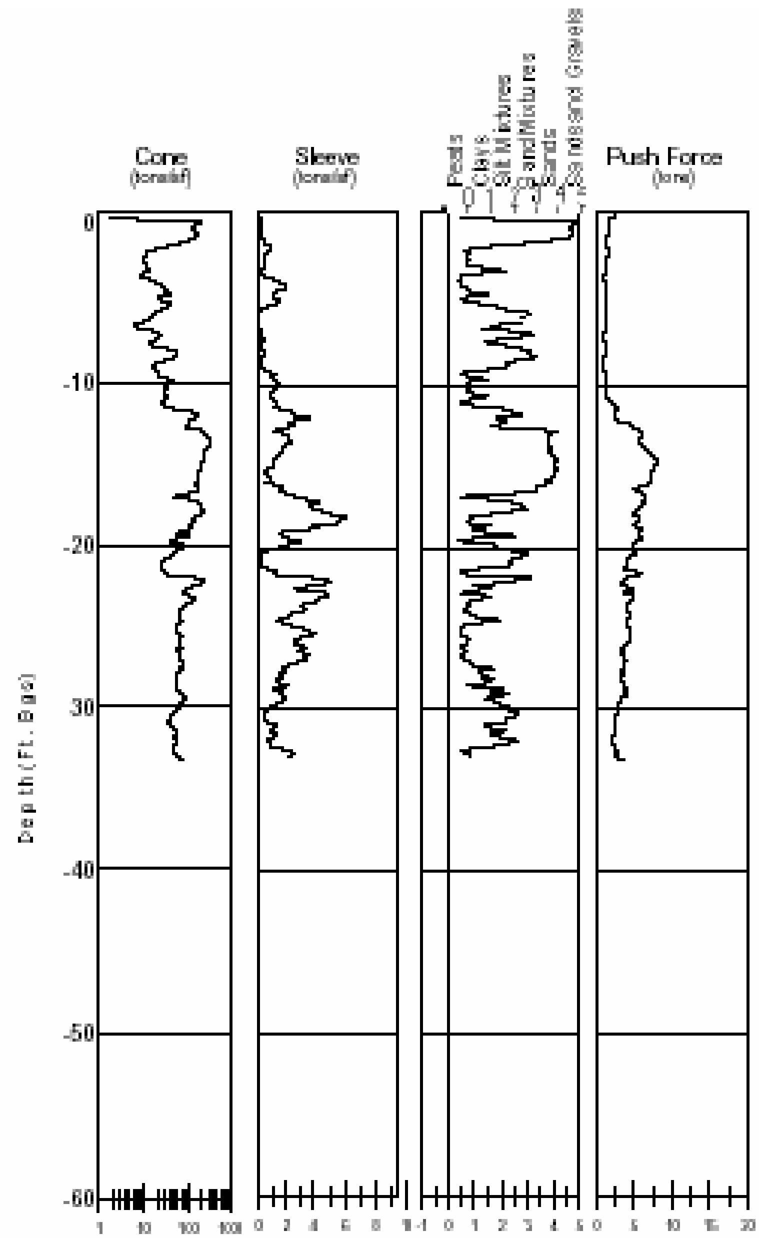
Prepush Depth (Ft) 0.00

Probe Depth (Ft) 20.41

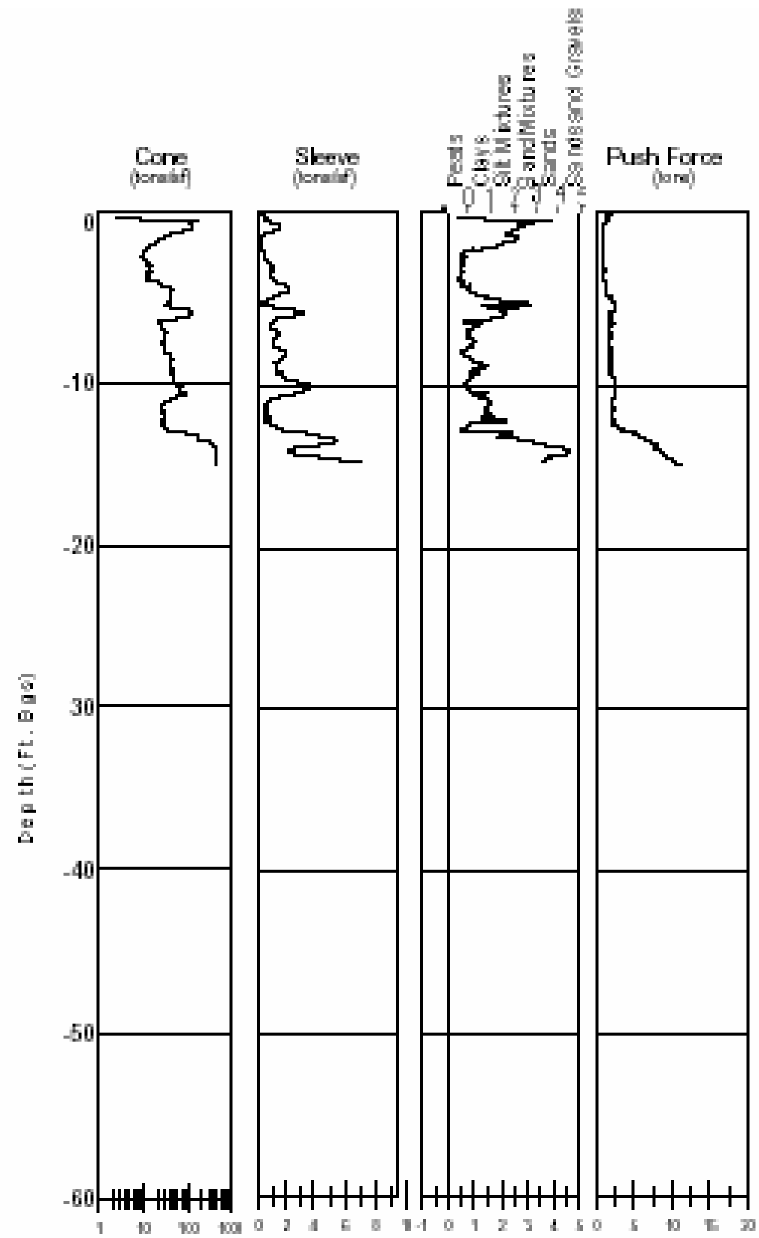
Scale 1"=10'

Project: Rickenbacker

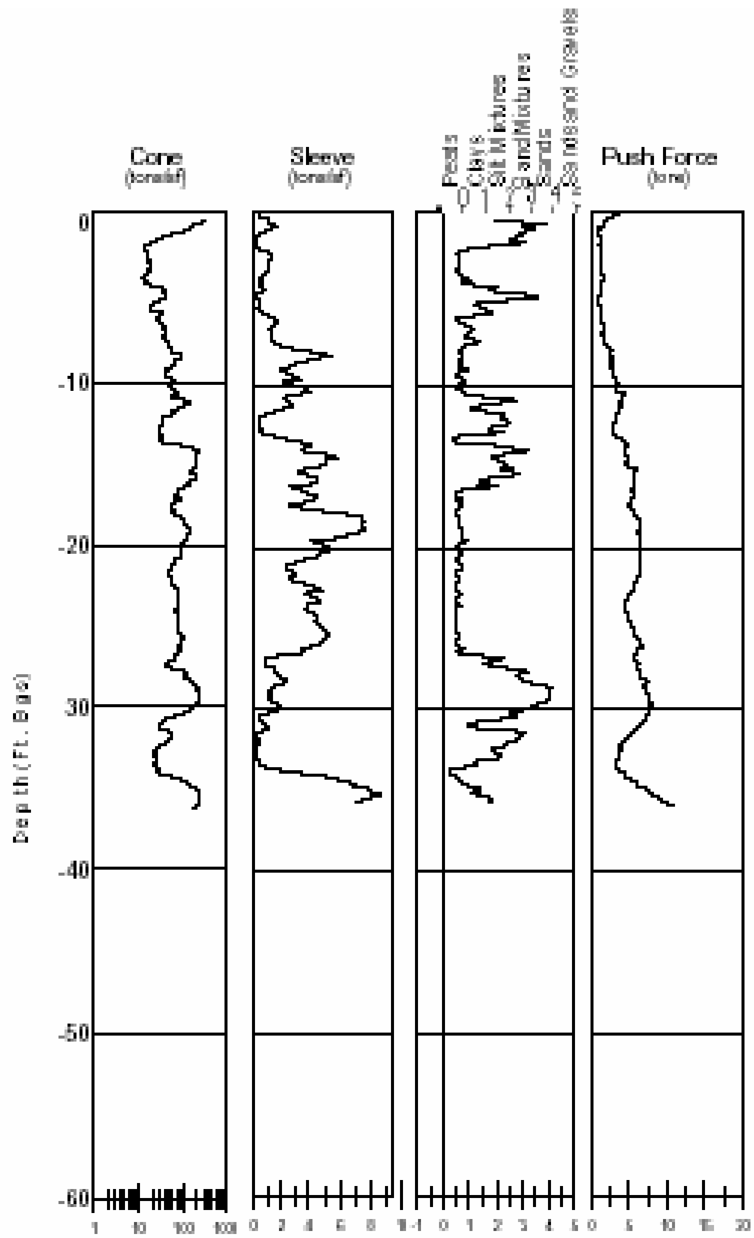
Push Name SCAPS12.QNF



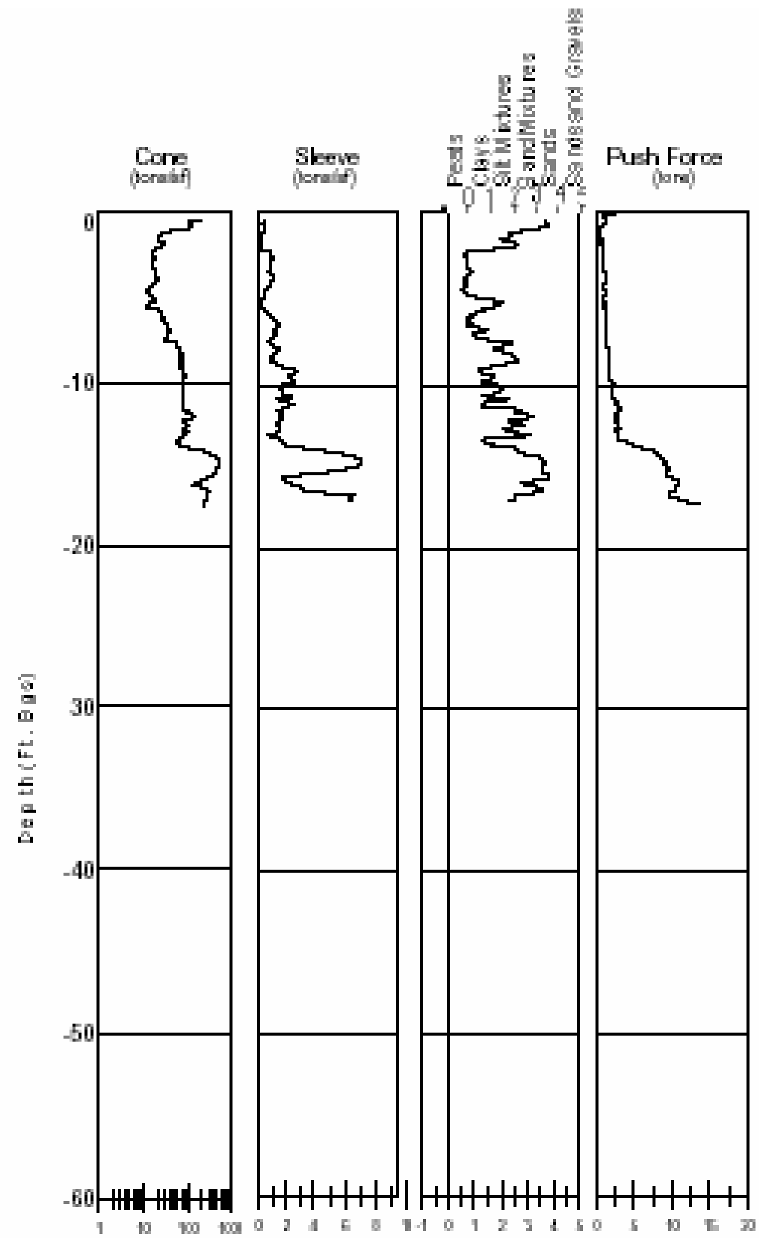
NWK *SCAPS*	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/16/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 33.38 Scale 1"=10'	Project: Rickenbacker Push Name SCAPS13.QNF



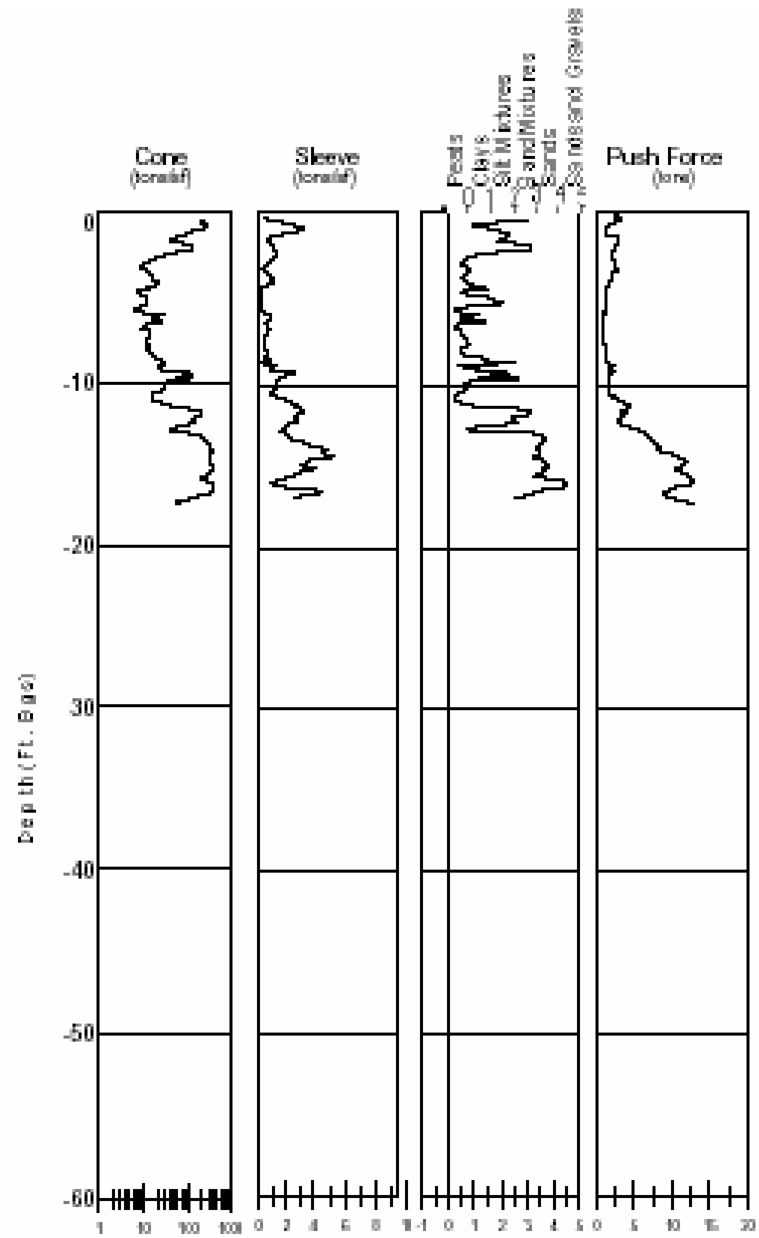
NWK *SCAPS*	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/17/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 15.53 Scale 1"=10'	Project: Push Name SCAPS14.QNF



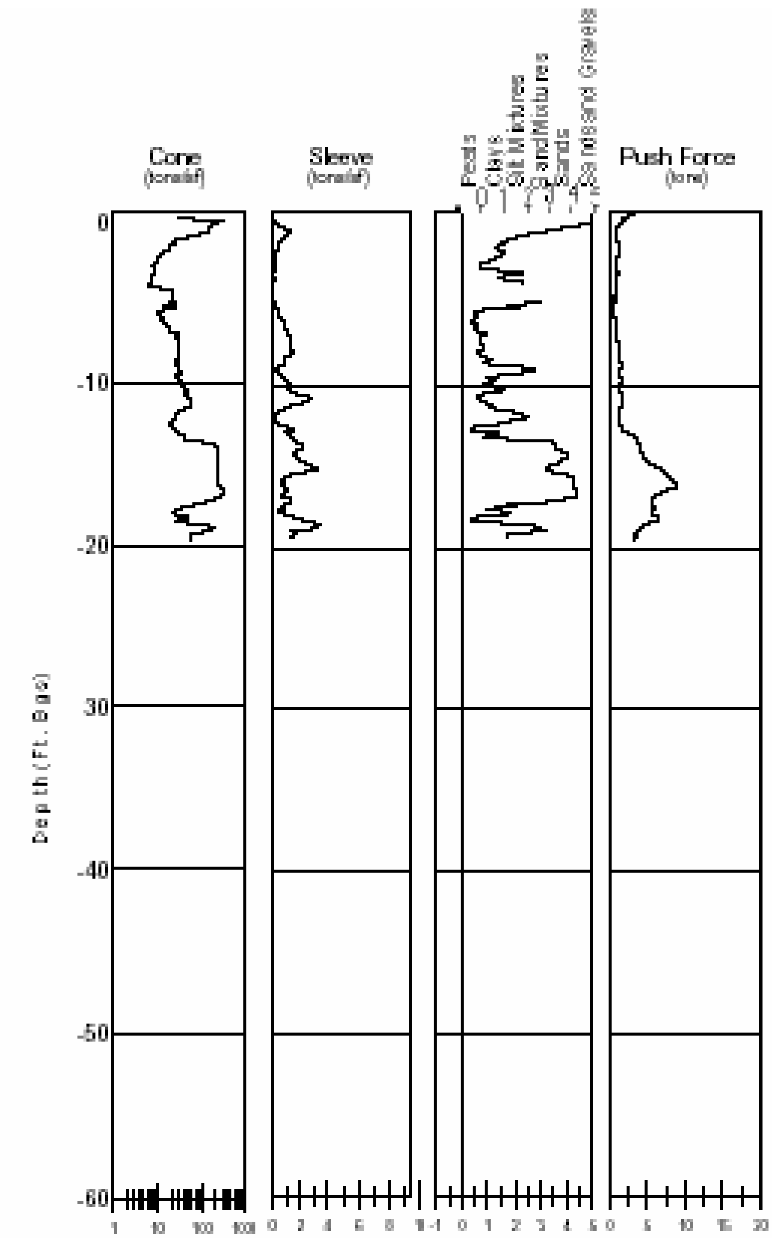
NWK SCAPS	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/17/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 36.34 Scale 1"=10'	Project: Push Name SCAPS15.QNF



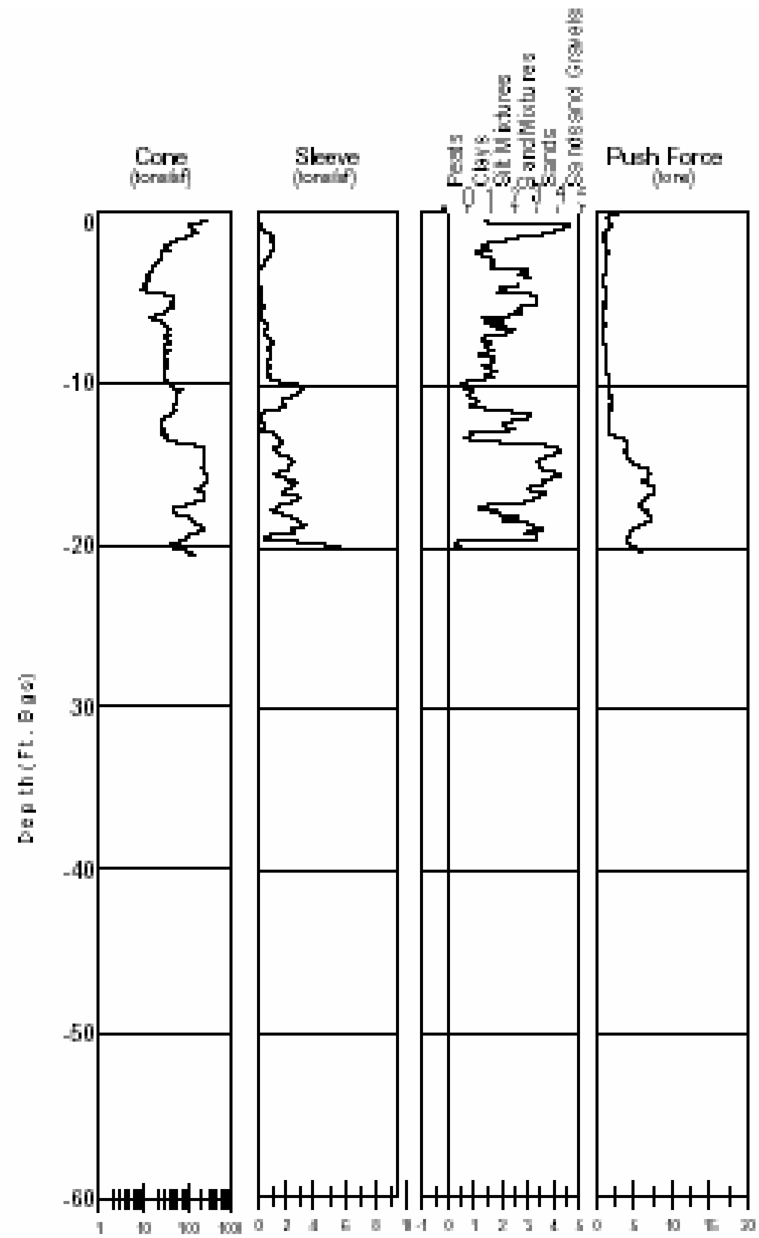
NWK *SCAPS*	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/17/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 17.85 Scale 1"=10'	Project: Push Name SCAPS16.QNF



NWK *SCAPS*	Site Characterization and Analysis Penetrometer System US Army Engineer District Kansas City Geotechnical Branch	Push Date 12/17/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 17.75 Scale 1"=10'	Project: Push Name SCAPS17.QNF



NWK *SCAPS*	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/16/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 20.04 Scale 1"=10'	Project: Rickenbacker Push Name SCAPS18.QNF



NWK SCAPS

Site Characterization and Analysis Penetrometer System

U.S. Army Engineer District Kansas City Geotechnical Branch

Push Date 12/17/20

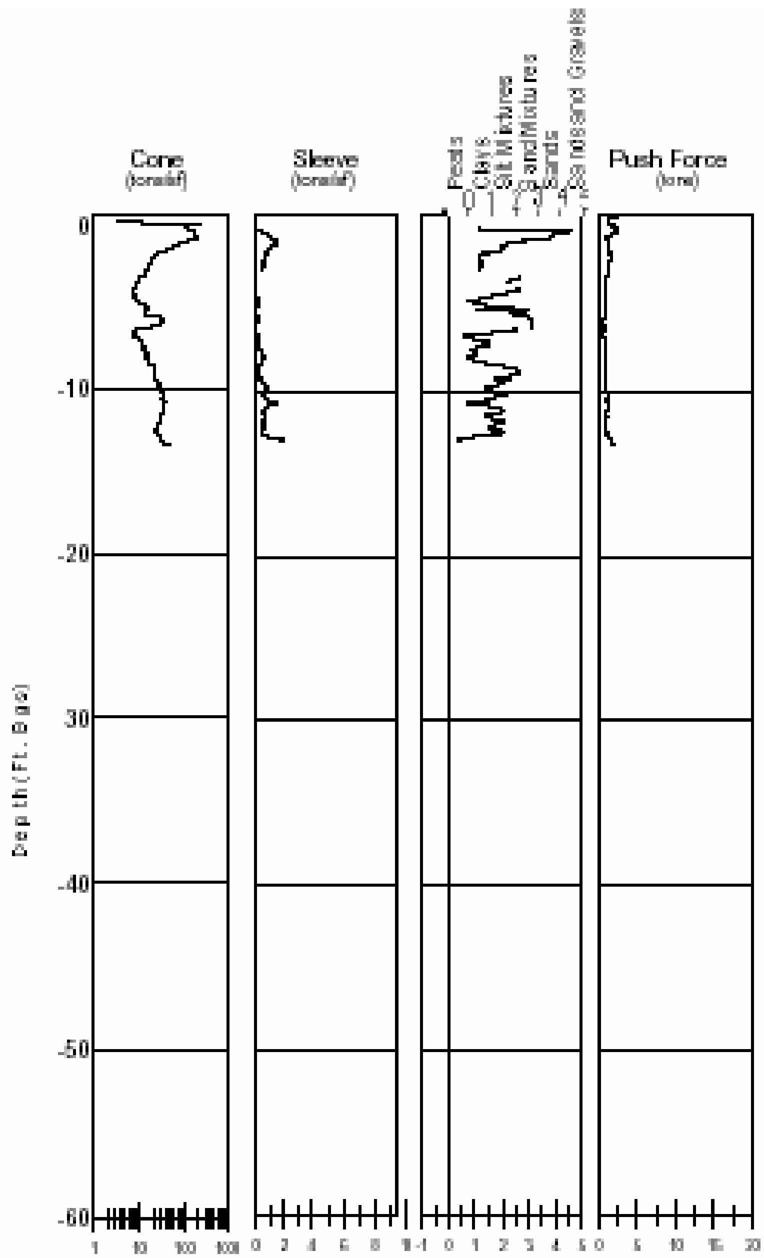
Prepush Depth (Ft) 0.00

Probe Depth (Ft) 20.92

Scale 1"=10'

Project: Rickenbacker

Push Name SCAPS19.QNF



NWK
SCAPS

Site Characterization and Analysis Penetrometer System

US Army Engineer District Kansas City Geotechnical Branch

Push Date 12/17/20

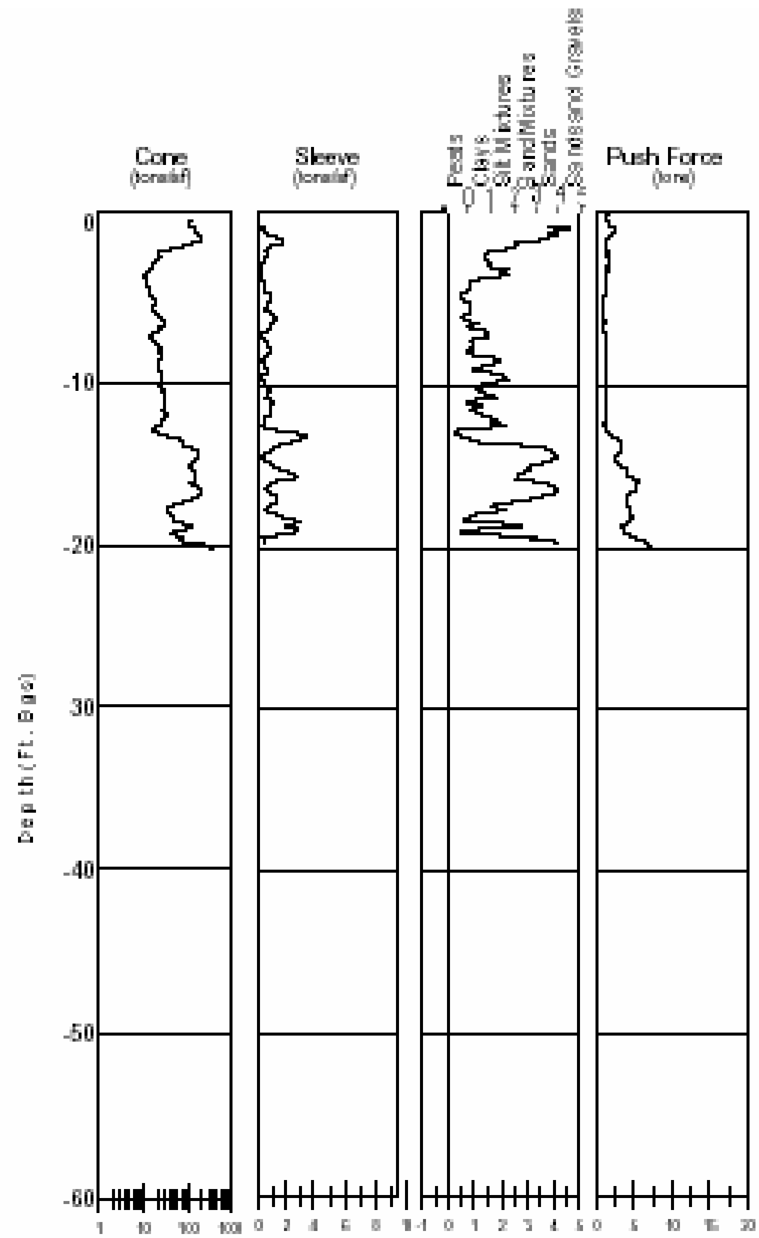
Prepush Depth (Ft) 0.00

Probe Depth (Ft) 13.81

Scale 1"=10'

Project: Rickenbacker

Push Name SCAPS20.QNF



NWK
SCAPS

Site Characterization and Analysis Penetrometer System

U.S. Army Engineer District Kansas City Geotechnical Branch

Push Date 12/17/20

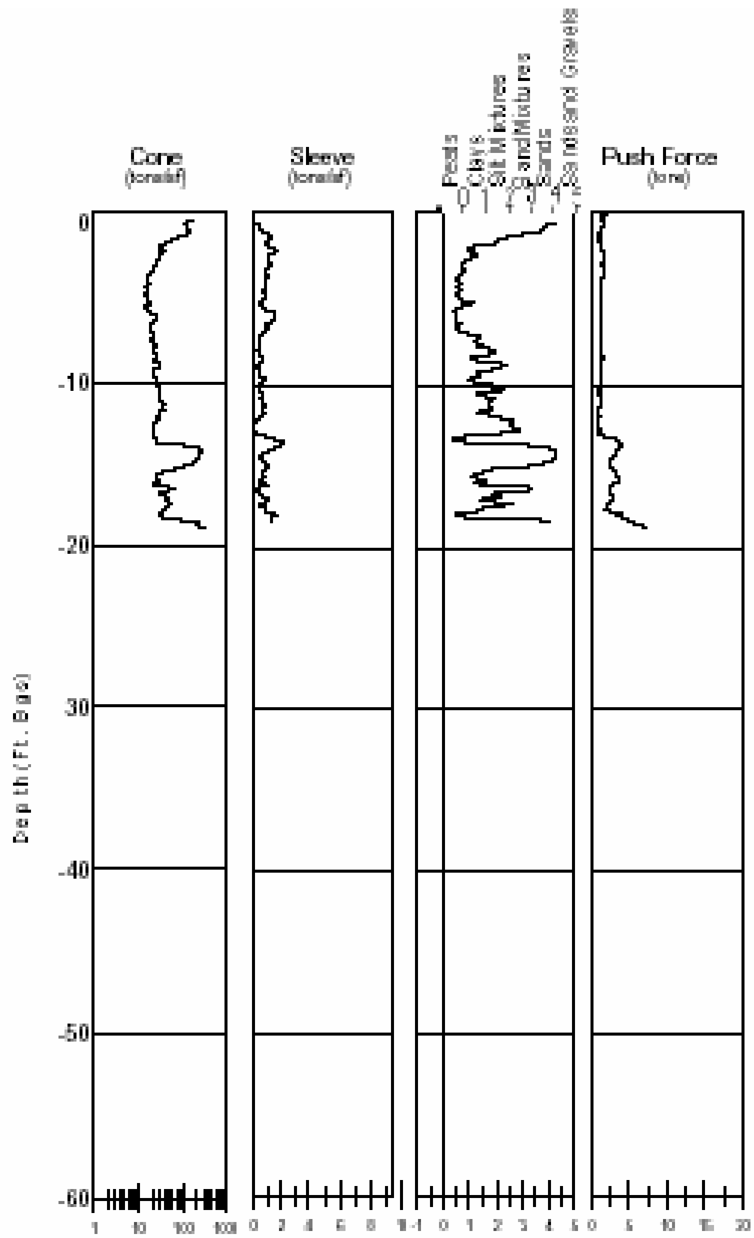
Prepush Depth (Ft) 0.00

Probe Depth (Ft) 20.54

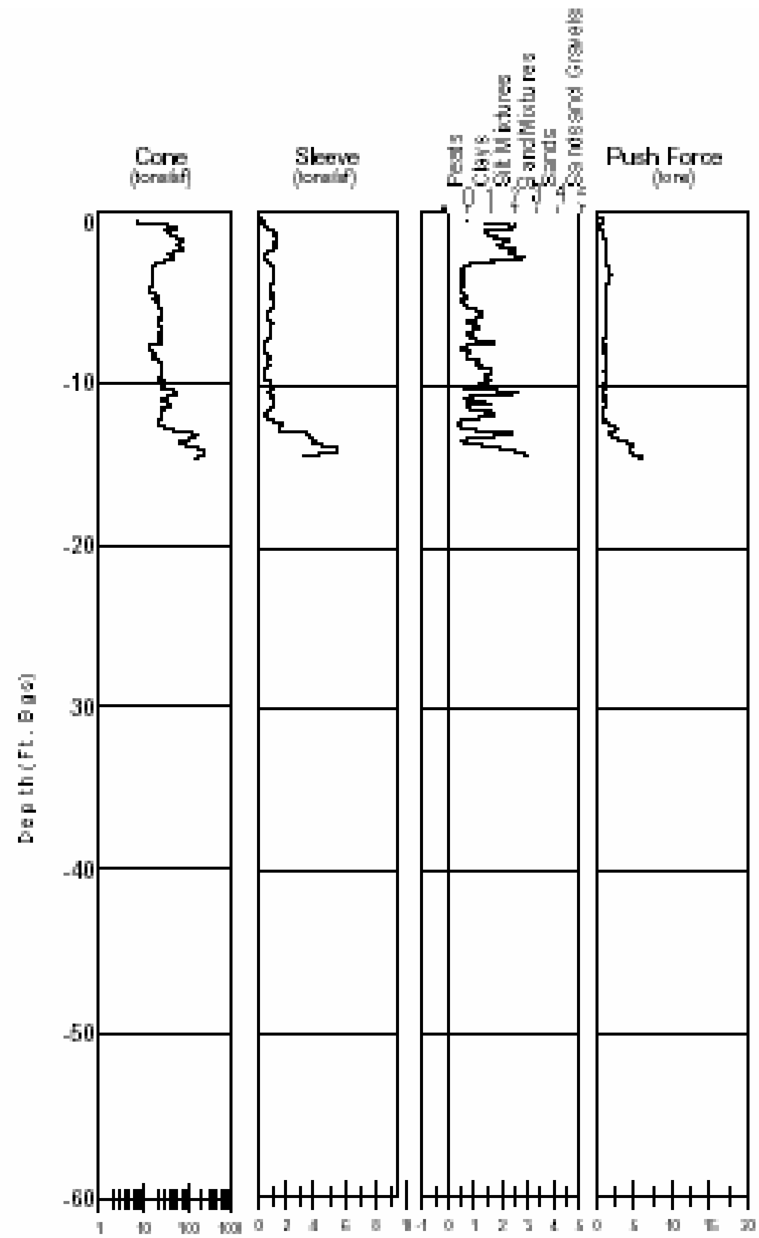
Scale 1"=10'

Project: Rickenbacker

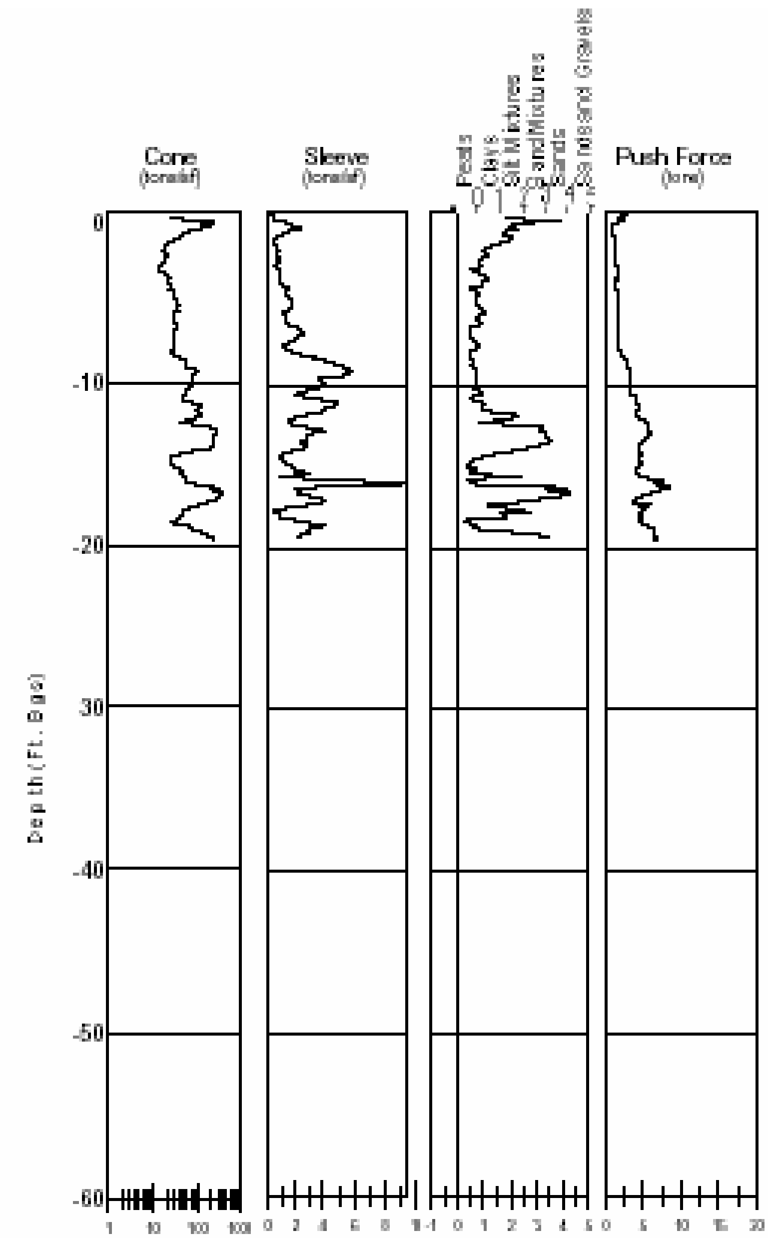
Push Name SCAPS21.QNF



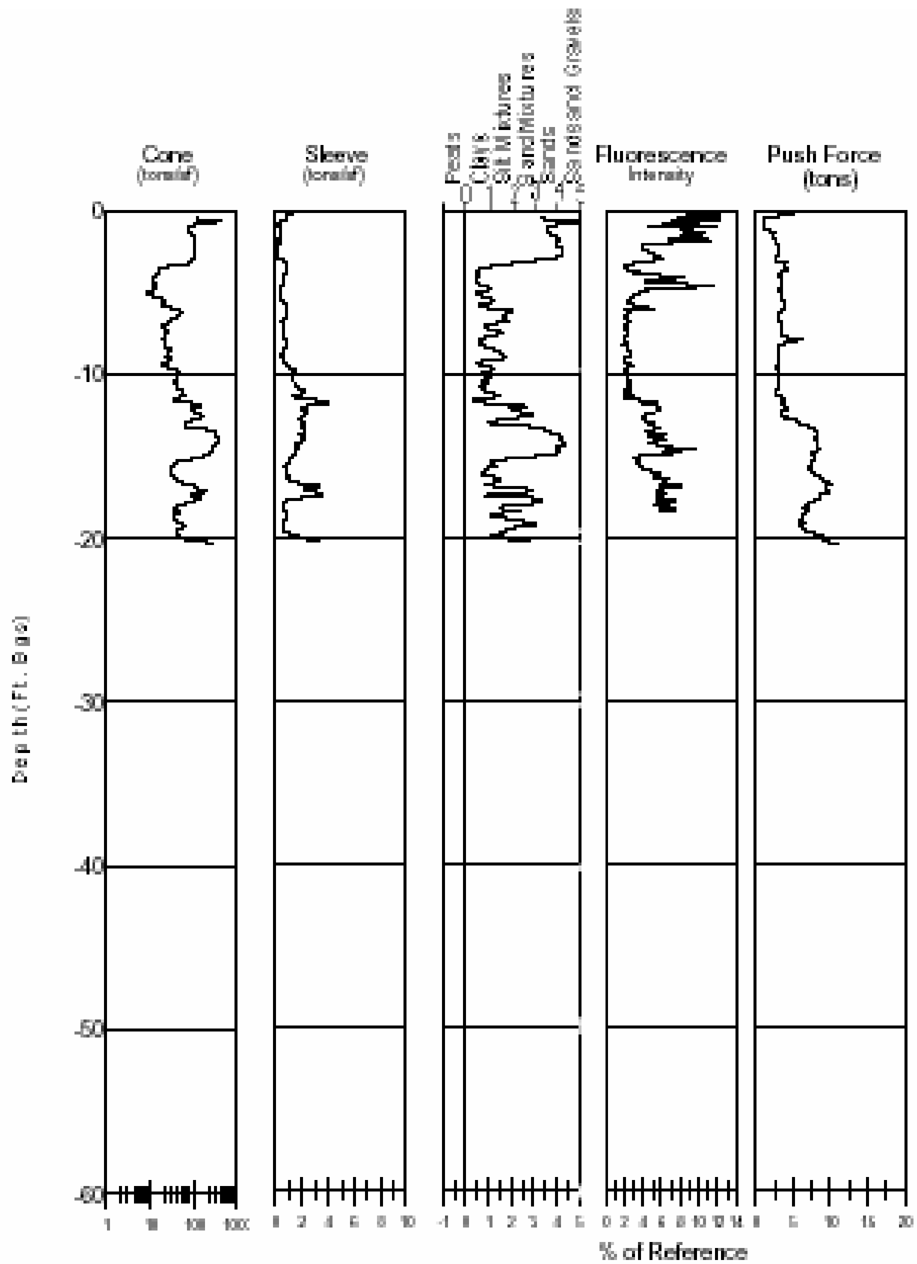
NWK *SCAPS*	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/17/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 19.23 Scale 1"=10'	Project: Rickenbacker Push Name SCAPS22.QNF



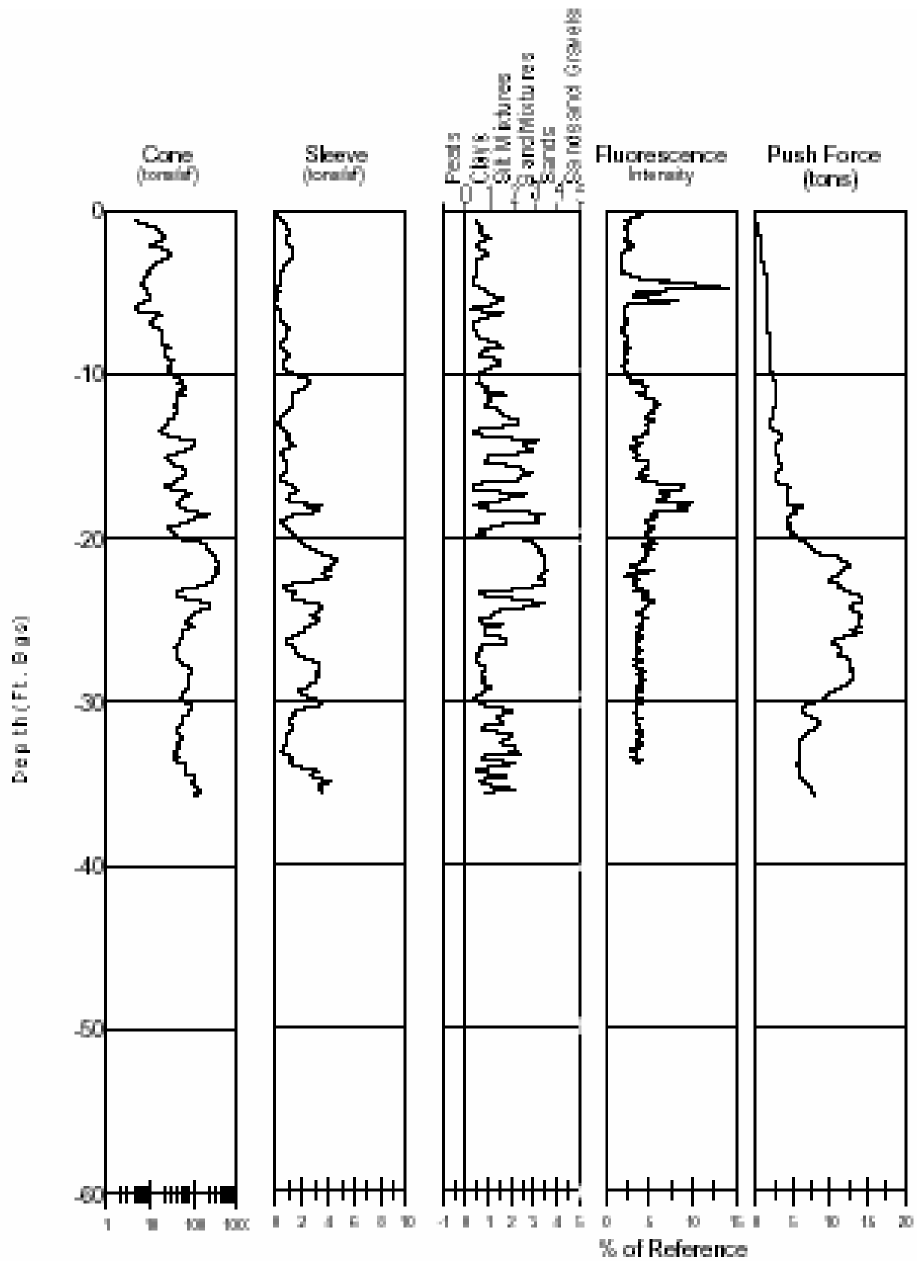
NWK SCAPS	Site Characterization and Analysis Penetrometer System; U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/17/20	Project:
		Prepush Depth (Ft) 0.00	
		Probe Depth (Ft) 15.02	
		Scale 1"=10'	Push Name SCAPS23.QNF



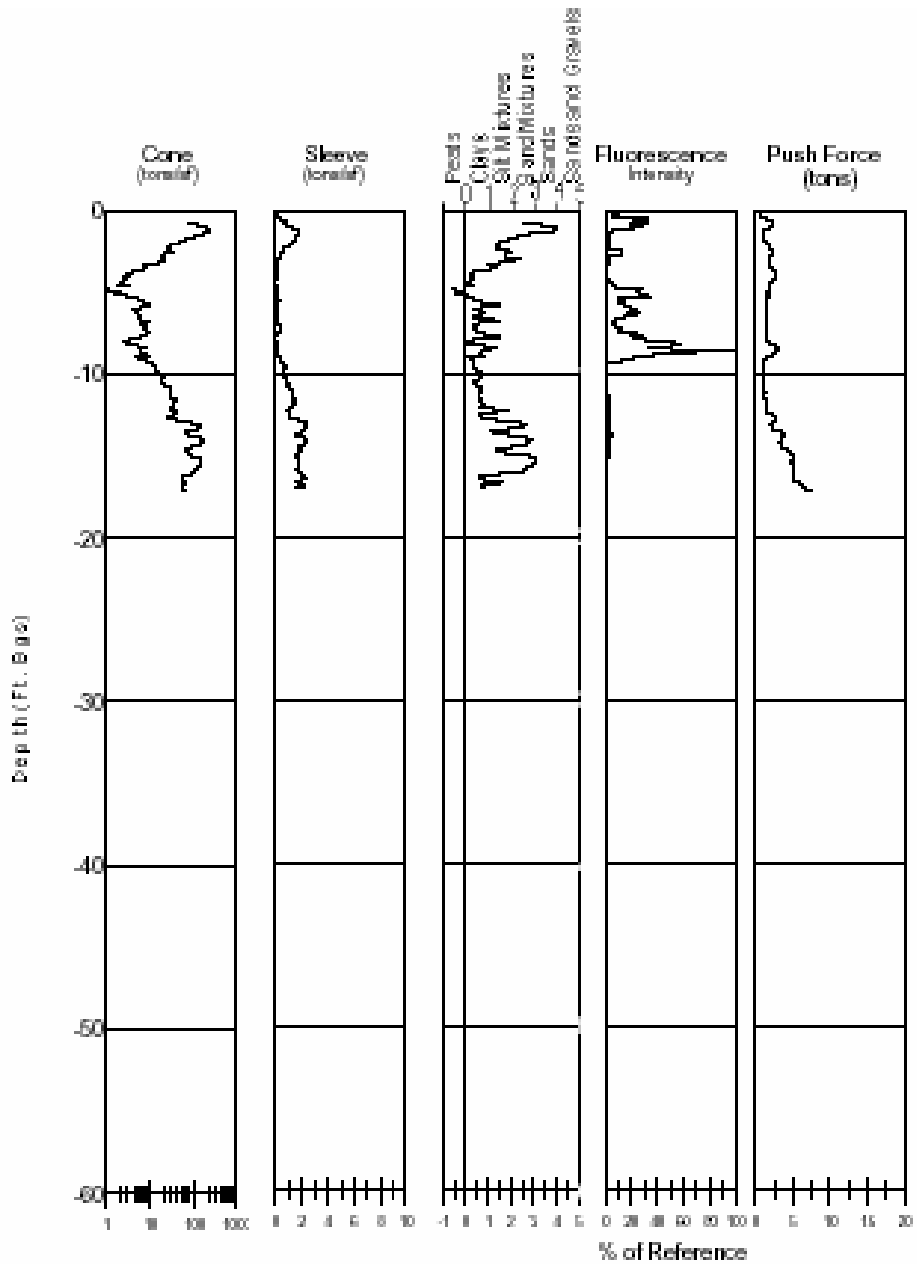
NWK *SCAPS*	Site Characterization and Analysis Penetrometer System US Army Engineer District Kansas City Geotechnical Branch	Push Date 12/17/20 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 20.01 Scale 1"=10'	Project: Push Name SCAPS24.QNF



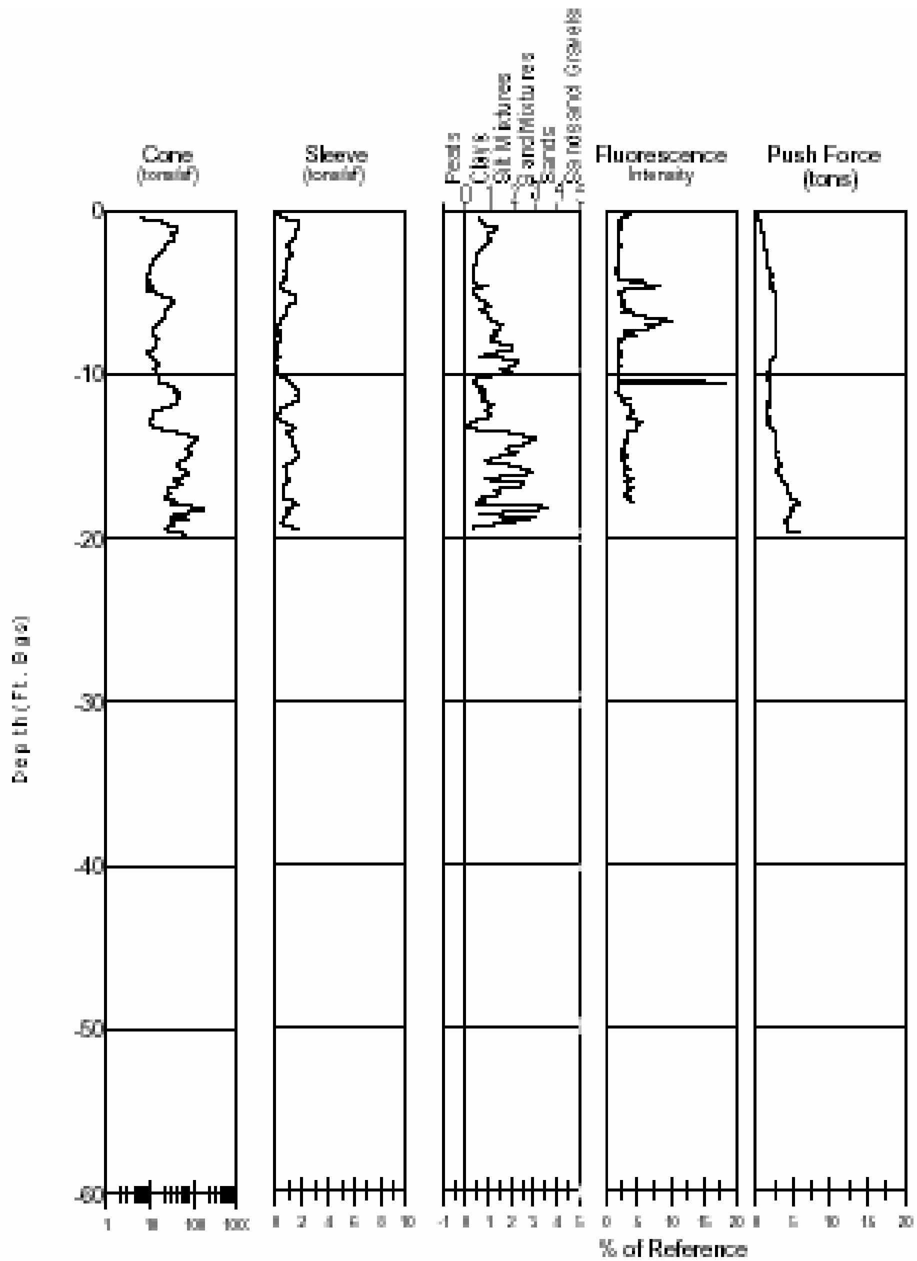
NWK *SCAPS*	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/15/200 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 20.44	Project Rickenbacker Site 41 Push Name SCLIF01.QNF



NWK *SCAPS* Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/15/200 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 35.84	Project Rickenbacker Site 41 Push Name SCLIF02.QNF



NWK *SCAPS*	Site Characterization and Analysis Penetrometer System U.S. Army Engineer District Kansas City Geotechnical Branch	Push Date 12/15/200 Prepush Depth (Ft) 0.00 Probe Depth (Ft) 17.19	Project Rickenbacker Site 41 Push Name SCLIF07.QNF



NWK

SCAPS

Site Characterization and Analysis Penetrometer System

U.S. Army Engineer District Kansas City Geotechnical Branch

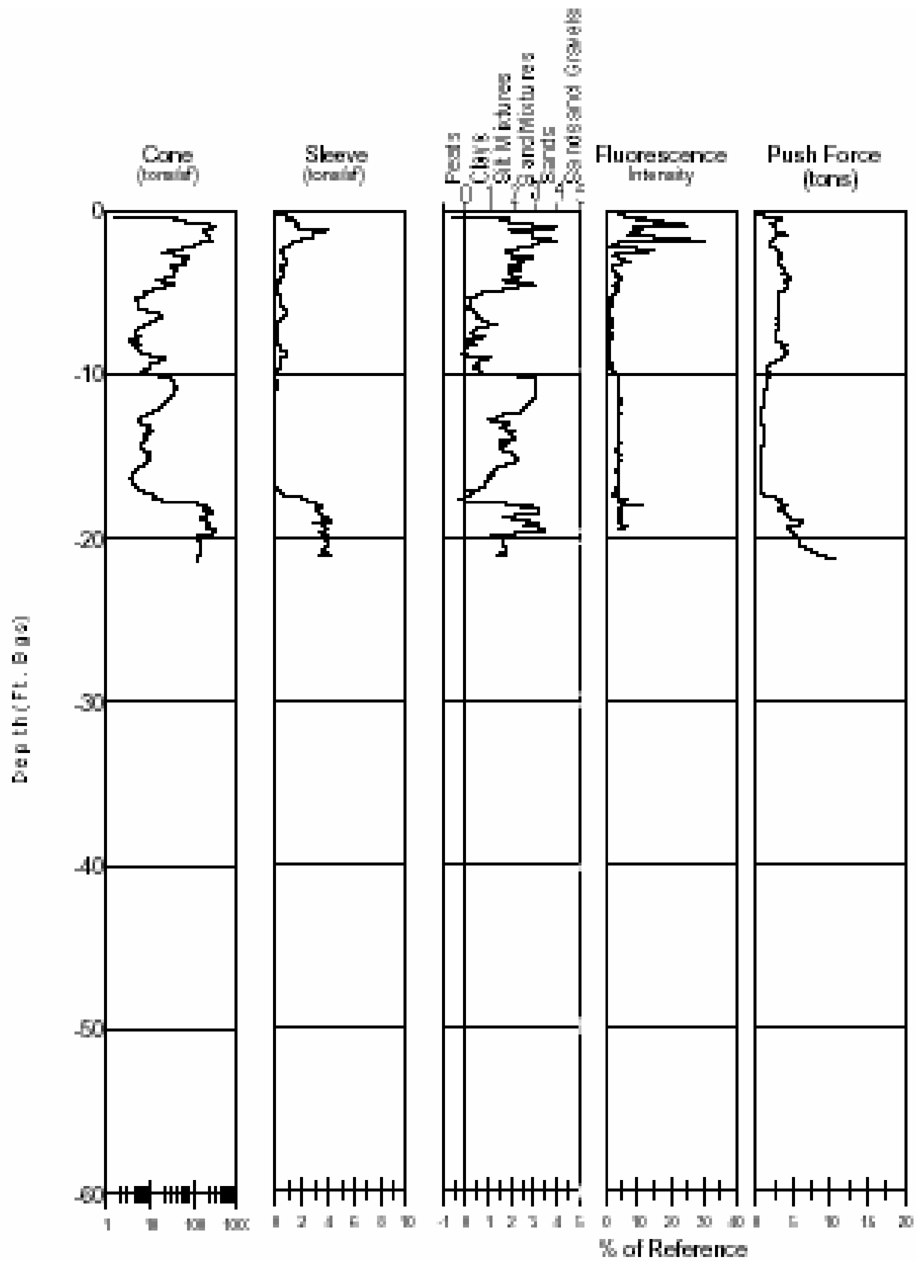
Push Date 12/15/200

Prepush Depth (Ft) 0.00

Probe Depth (Ft) 19.81

Project Rickenbacker Site 41

Push Name SCLIF08.CNF



NWK
SCAPS

Site Characterization and Analysis Penetrometer System
U.S. Army Engineer District Kansas City Geotechnical Branch

Push Date 12/15/200

Prepush Depth (Ft) 0.00

Probe Depth (Ft) 21.44

Project Rickenbacker Site 41

Push Name SCLIF85.QNF